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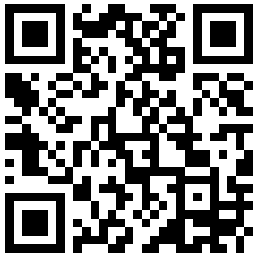

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THE NEWCOMEN SOCIETY

for the study of the history of

ENGINEERING and TECHNOLOGY

TRANSACTIONS

Volume V

1924-1925

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ENGINEERING and TECHNOLOGY

TRANSACTIONS

Volume V

1924-1925

LONDON:
Printed for the Society by
The Courier Press, Leamington Spa
1926

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ERRATA IN TRANSACTIONS, VOL. IV.

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Notes on Coalbrookdale, and the Darbys

BY

J. W. Hall, M.Inst.C.E.

(*Read at the Iron and Steel Institute, Westminster, 8th October, 1924.*)

At the Summer Meeting at Shrewsbury were exhibited certain documents, kindly lent to the Society, dealing with the history of Coalbrookdale and of the Darby family, and the writer was asked to prepare some account of their contents. Particulars of these documents are given at the end of this paper. Accordingly the writer has selected from them information of interest hitherto unpublished, and has added thereto certain facts gleaned from various other sources. It would appear that Dr. Samuel Smiles had access to these documents, because phrases from them appear in his " Industrial Biography."

It is clear that the Romans worked coal in Shropshire, because coal has been found amongst the ruins of Uriconium, and in a hypocaust discovered at Oakengates in 1797, but there is no evidence that they made iron in the county. Smiths are mentioned in Shropshire in Domesday Book, but there is nothing to imply that they produced the iron from the ore. From the thirteenth century onwards, there are frequent references to the use of coal in Shropshire.

There is ample evidence of the existence of collieries, furnaces and forges in the neighbourhood of Coalbrookdale before Abraham Darby I. removed there from Bristol in 1708, and together with Thomas Bayliss, his brother-in-law, took over from the Corfields family a lease for its then unexpired period of a blast furnace. This lease, which still exists, was originally granted in September, 1696, by Sir Basil Brooke to Shadrach Fox; the latter disappeared, and is said to have gone to Russia with Peter the Great. The lease was then taken over by the Corfields. Under this lease the " Chark coal " at these furnaces was to be paid for at the rate of £2. 6s. per load.

At that date a better situation for iron making could hardly have been selected. Iron ore and limestone were readily obtainable; ample water power existed; the district still contained large quantities of timber, which had practically disappeared from most other places where iron ore was procurable. According to Darby's daughter-in-law, money at that time was so scarce in the district, that trade was still conducted largely by barter, so that labour would be cheap. Coalbrookdale, moreover, was only a few miles from Watling Street, one of the most important roads in the kingdom.

But the outstanding advantage of Coalbrookdale was its position on a navig-

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able river, giving access to Bristol, one of the leading seaports of the kingdom, and to this—coupled with the energy and enterprise displayed by Abraham Darby, his son and his grandson—the success of Coalbrookdale is attributable. Although navigation on the Severn was occasionally interrupted by floods or droughts, it was infinitely cheaper than transport by road, at a time when such roads as existed were in a deplorable condition, so that men and materials had to be carried almost entirely on the backs of horses. In 1745 the Young Pretender penetrated to Derby, only because the army at Newcastle, for want of passable roads could not cross to the west coast to intercept him.

The bellows for Sir Basil Brooke's blast furnace were worked by water power, and the ironstone was purchased from various persons who worked mines in the neighbouring parishes. The venture seems to have been at once successful, a second furnace was soon started, and Darby was arranging to open works in other districts when his death, in May, 1717, put an end to these schemes, and necessitated a contraction of responsibilities. Thomas Goldney and his son, who had been Darby's agents and bankers in Bristol, and Richard Ford, Darby's clerk, who subsequently married his eldest daughter, joined the widow and formed the Coalbrookdale Company.

A detailed inventory of " ye quick and dead stock " taken in July, 1718, shows the variety of castings then made. In the " Coal Yard " was a stock of " brays," some cords of wood, and a large quantity of turf. At the old Blast Furnace were " six stacks of coaks," and fifteen at " ye Coal Hearths." The " Piggs " were valued at £8 10s. per ton, and the " Sculls " at £2 per ton. Bar iron at this time cost £21 per ton. There were three " Air Furnaces " in the foundry, but most of the castings were run directly from the blast furnace.

For over a hundred years attempts to use pit coal in place of wood charcoal for iron-making had been made in various parts of the Kingdom, and several patents had been granted for its use for this purpose, but none had been successful, although pit coal had been found satisfactory when employed for other manufacturing purposes. One of the difficulties probably was the insufficiency of the blowing power then generally available. It is thus evident that the attention of many persons had been called to the necessity for using pit coal for smelting if the manufacture of iron was to be any longer carried on in this country. According to Scrivenor, who may have got the information from the works, coal was first used for the purpose at Coalbrookdale in 1713, when the furnace charge consisted of five baskets of coke, two of brays, and one of peat, and only 5 to 10 tons of iron were made per week.

In 1720 the Coalbrookdale Company took over Thomas Stanley's tenancy of the Middle Forge, purchasing from him his utensils and stock of iron.

Heavy castings were now run in the foundry. The earliest " Fire Engine "

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work was supplied to Stanier Parrot, Esqre., of Coventry and Bedworth in 1718, and in 1725 " 1 Cillinder, 1 Bottom, 1 Pistern and 4 Pipes," weighing 74 cwt. 1 qr. 11 lb., were delivered to him. In 1724 a " Cillinder " had been sent to Swannington, and " a Cillinder and Bottom, a Pistern, 2 Brass Pipes and Wrought Iron about 30 Pins " had been taken to " Harding near Chester," whither other articles were sent in 1726 and 1727. Sir Richard Newdigate had " 1 Cillinder, 1 Bottom, 1 Pistern . . . and 3 Pitt Barrells " (*i.e.* Pump pipes), weighing 51 cwt. 3 qr. 25 lb., and William Jordan & Co., of Hampton, had 1 Pipe bored 8 cwt., and Pipes unbored 16 cwt. 3 qr. 25 lb., in 1725. Similar articles were supplied to Sir George Beaumont, Lord Middleton, and George Sparrow, of Darlaston, in 1727; to Sampson Lloyd & Co., in 1730; to Joseph Hornblower, Birmingham, Alderman Ridley, Newcastle on Tyne, and Thomas Allan, Esq., of Allan's Flats, near Newcastle, in 1731; to The Earl of Scarborough in 1733, to Sir George Beaumont for Wyken, and to Joseph Hornblower in 1734; to Henry Lambton, Esq., Lambton nr. Durham, and William Richardson, Esq., Dudley, in 1735; to Lord Middleton, Lord Dudley, and Buslome Sparrow in 1736. This list could be greatly extended.

Anticipating an increased demand for pipes and fire engine work consequent on the expiration in 1733 of Savery's patent which covered the atmospheric engine, Richard Ford, in 1732, concluded an agreement with George Weld, of Willey, for a lease of the furnace there to the Dale Co. for twenty-one years, the Lessor engaging " to deliver at the furnace such quantity of coles that shall be wanting for carrying on the work, but such as shall be approved of," and also ironstone at fixed rates. It appears that the furnace was not again worked exclusively with charcoal.

There was always a shortage of water at the Dale in the summer, when the furnaces had to be run with slack blast; indeed, in most years, they had for a time to be blown out entirely. To avoid this difficulty, Abraham Darby II., when he came of age in 1732, persuaded Richard Ford to put in an atmospheric engine to raise the water, which had already passed over three or four wheels, so that it could be re-used. This scheme was completed in 1742-4, when wooden tubs replaced the leather bellows. A letter exists which shows that this engine worked two 18in. pumps, 7ft. 9in. stroke, to lift the water through 84 feet.

Richard Ford died in 1745. During the next few years Darby, instead of purchasing coal and ironstone from others, arranged with the neighbouring landowners to lease mines from them, and raised his own minerals at Ketley, Dawley, Horsehay, and Malins Lee. The Horsehay Furnaces were started in 1744-5, and others in 1756, which produced over 25 tons per furnace per week.

The demand for castings for " fire engines " increased, and in 1762 an agreement was come to by Abraham Darby on behalf of the Coalbrookdale Company, Isaac Wilkinson for the Bersham Company, and John Wilkinson for the New

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Willey Company, to charge identical prices for such work. These castings were of considerable size, the cylinders being 63 to 70 inches diameter by 10 feet stroke.

Abraham Darby II. died in 1763, and Richard Reynolds, of Bristol, his son-in-law, who had been a partner since 1756, took charge. According to a statement written by Abiah Darby, Abraham Darby's widow, the materials for the works were carried on pack-horses until " he (Abraham Darby II.) got roads made and laid with sleepers and rails, as they have them in the North of England," and she adds " iron wheels and axle trees for these wagons was, I believe, my husband's invention." These timber rails, being costly to maintain, were later replaced by iron ones, and Mr. W. G. Norris, who became the manager of Horsehay in 1866, and who consequently had a good opportunity of ascertaining the facts, writing to Mr. Monks, said, " there is little doubt but that the cast iron rails were not laid down for some years after the decease of Abraham Darby." John Randall says that 5 to 6 tons of rails were cast on 13th November, 1767. The timber rails were 3½in. by 4½in., and the cast iron 3¾in. by 1¼in. thick, mostly in 6 foot lengths, having two end and two intermediate snugs for trenails to attach them to the timbers. The load carried by the packhorse was 3½ cwt., while the wagons carried 35 cwt., and Mrs. Darby says, " One wagon with three horses will bring as much as 20 horses used to bring on horses' backs."

Richard Reynolds, writing to Earl Gower on the 27th March, 1785, states that there were then 20 miles of iron railways in connection with the Works (which Mrs. Darby says cost over £800 per mile). He mentions that the Company then owned 10 blast furnaces, 9 forges, and 16 fire engines, and that the Company still employed a capital of £100,000, though bad trade had caused them to stop two blast furnaces.

Making pig iron with pit coal, suitable for foundry or forge, was now an accomplished fact: but charcoal was still employed for converting the pig iron into wrought iron, although some coke was used for the purpose; to this day the terms " charcoal finish " and " coke finish " are employed in the tinplate trade. Except at Coalbrookdale itself, the forges producing wrought iron were not at the same places as the blast furnaces, nor did they belong to the same persons, but were scattered about wherever water power and charcoal were obtainable.

In 1760 the Company had leased the Town Mills at Bridgnorth, merely to get water power, and ran a forge there for some years. Probably it was the scarcity of charcoal which induced Richard Reynolds in 1766 to encourage the brothers Cranage in their use of an air furnace for effecting the conversion of pig into wrought iron, because it was hoped that the metal not being in actual contact with the fuel, it would not pick up sulphur and other impurities from it. This partially successful experiment nearly anticipated Cort's puddling process, invented 17 years later.

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In 1772 charcoal pig was sold at £7 12s. 6d., coke pig at £6 10s., bar iron at £20, " boyler " plates at £28 per ton. The plates were all hammered out, 40lb. being a notable size, and when in 1798 they were rolled at Horsehay, 2 tons 0 cwt. 1 qr. 12 lb. of slabs sufficed to make " 233 boiler plates sorted sizes," so that the average weight of each was only about 18 lb.

In 1770 large castings were being sent to the Cornish Mines and to the North of England, but the delays in transit were so serious—one cylinder took twelve months to reach Newcastle—that the Iron Masters on the Severn applied to Parliament in 1771 for powers to construct towing paths, so that horses could drag the barges instead of men. These men formed a close community, and put such obstacles in the way that nothing was done until 1799, by which time much of the heavy trade had been diverted elsewhere.

Abraham Darby III., soon after he came of age in 1776, had opened negotiations with neighbouring land owners, and at once sunk collieries and started two furnaces at Madeley Wood.

As the demand for iron still increased, James Watt was consulted, and put in his engines at Ketley and the Dale. In his letter to William Reynolds, dated 2nd January, 1781, Watt offered to put in a new " returning engine " at the Dale to have a cylinder 66 inches diameter, by 9 feet stroke, to work two 26 inch pumps, capable of raising 516,000 cubic feet of water 93 feet high, with a consumption of coal guaranteed not to exceed 148 cwt., the mean effective pressure on the piston being calculated as 9.7 lb. per square inch. Watt further states that the existing Newcomen engine was taking 388.8 cwt. to raise the same quantity of water, and proposed as his premium one-third of the coal saved, reckoned at 2s. 6d. per ton, payment to be determined by the reading of a counter to be affixed to the engine. This guarantee is equal to a duty of 180,782 lb. raised one foot high per lb. of local coal, and Watt seems to have expected a result one-third better, which would be nearly half the duty obtained from Cornish engines 75 years later when using Welsh coal and considerably higher boiler pressures.

Some of the cost accounts from 1810 to 1813 are very detailed. The following extracts may be of interest. Originally it seems 3.1 tons of coal were required to produce a ton of coke, but in 1810 2½ tons sufficed, and it required 34 cwt. of coke to make a ton of pig iron, the cost at Horsehay then being :—

	£	s.	d.
Coals—5 tons @ 6/6 per ton long weight	2	12	6
Mine—2 tons 4 cwts. @ 15/- long weight	1	13	0
Limestone—18½ cwts. @ 7/6 long weight		6	11
Labour and Drink		10	0
Use of Tools at Furnaces, Sand, etc.		2	0
Blast		3	7
New Hearths and Agency		2	0
Cost per ton, long weight, at Horsehay	£4	10	0

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At Dawley Castle, the coal being better, and the carriage from mines less, the cost was £4 4s. 0d.

The cost of conversion during the next few years varied as follows, all long weight.

	£ s. d.		£ s. d.
Pig	4 4 0	to	4 15 0
Refined Iron	5 4 2	to	6 1 0
" Half Blooms "	6 15 6	to	8 15 1
Merchant Bar	8 7 0	to	10 3 0

There were two blast furnaces at Dawley Castle, producing 58 to 60 tons each per week, blown by an engine which consumed 280 tons of large coal per month. The open sand casting for use in the various works were cast here, moulding costing 4s. 6d. per ton.

In connection with Horsehay, the Company worked collieries and mines at Dawley and Lawley Bank. In 1826, 43 pits, 12 for coal and 31 for ironstone, were producing 9,000-9,500 tons of coal, and 4,200 tons of ironstone per month, all calcined on the spot in heaps of 1,000 to 3,000 tons. The cost of raising was about 3s. 9d. per ton for coal, and 6s. 10d. per ton for ironstone, the men receiving 2/- to 2/6 per day. At that time there were at Horsehay three refineries, four charcoal fires, two forges, and a rolling mill. Two engines delivered the blast into a common water regulator 60 feet long, 6 feet deep, and 3 feet wide, having an open bottom, and standing in a trench. A 3 feet pillar of blast was maintained, and in addition to the above, these engines blew a cupola and eleven smiths' hearths. The furnaces produced 50 to 55 tons of pig per week; the refineries 650 tons of best plate iron per month, which was puddled on sand bottoms in heats of $3\frac{3}{4}$ cwt., six heats being worked per turn. Wages ran from 14/- to 20/- per week, but the puddlers' underhands only received 1/8 per day. The puddled balls were hammered into blocks, which were nicked and broken. Some scrap was heated in clay pots and hammered into billets. For the plate mill, refined iron only was used, which after puddling was stamped, and these stamps were broken and piled on benches by women. The Mill contained a plate mill, large and small bar mill, and a slitting mill: 560 to 570 tons of forged iron yielded 520 to 550 tons of finished iron per month.

In 1832 Joseph Hall's " pig boiling " process of puddling was introduced, when the charge was promptly altered to one half refined iron and one half raw pig, and the refineries soon after ceased working entirely.

In 1833 guide rolling was introduced from Staffordshire, and in 1838 the hot blast was adopted, and raised the output to 80 to 90 tons per furnace per week, which was never exceeded. The closed top to the furnaces was tried in 1850, but two bad explosions caused its abandonment. The Horsehay Works eventually could produce 1,500-1,600 tons per month.

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In 1830 Abraham Darby III. had taken charge of the mines and works, and his brother Alfred of the offices. Abraham was constantly down the pits, both brothers were about at all hours of the day and night, and many abuses were stopped in consequence. Immediately 600-700 tons of coal were saved per month by using under the boilers the slack formerly thrown down the pit bank, where it fired and poisoned the neighbourhood. Pilfering was stopped, and great economy of stores effected. Refinery and flue cinder were put through the blast furnaces, and premiums on output raised the make from 50 to 60 tons, but so many rails, wheels, etc., disappeared in consequence that night watchmen had to be appointed. The puddlers' heats were increased, and proper yields required. A forge train and more powerful engines were put in, and wire rod was rolled directly from puddled iron instead of from billets made from scrap in charcoal hearths. Horsehay Farm was acquired, and the Company's own horses, which at one time numbered about 100, replaced hired teams. A brickyard was opened, and houses and a school built for the workmen.

When Abraham Darby gave up the active management in 1849, and Alfred died in 1852, the Company's prosperity declined. The blast furnaces and iron works have now gone: Horsehay is a bridge building yard: though the engine works and foundries are still running, they are under different ownership.

Appendix.

The exhibited documents, originals or copies, used in the preparation of the paper were as follows:—

1 MS. account of the work of Abraham Darby II. given by his widow, Abiah Darby, dated " Sunniside, 1763 " (see Plate I.).

2 A.L. James Watt, Birmingham, to William Reynolds, January 3, 1781, enclosing proposals by Boulton & Watt to the Coalbrookdale Company, dated January 2, 1781, for the erection of two new pumping engines one at the Dale and the other at Madeley Wood Furnace.

3 MS. " Some Accounts of the Family of the Darbys, being what Hannah Rose has heard her Parents, John and Grace Thomas, say concerning them," by the request of Sarah Darby, 1795.

4 MS. " Development of the Coal and Iron Industries in Shropshire " with notes as to the family pedigree. This is in the handwriting of William Darby.

5 MS. History of the Coalbrookdale Co. Apparently written by W. G. Norris, many years Manager to the Company.

6 A.L. Wilson Birkbeck to Abraham Darby III., dated "10 mo. 9th 82." Birkbeck was a cousin of Darby.

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7 MS. Report by John Curr, of Sheffield, to Richard Dearman, Coalbrookdale, dated May 25, 1793, as to methods for handling coal from the pits to the boats.

8 Sundry notices concerning the maintenance of order in the works at Coalbrookdale.

9 Photo Print. Engraving of Coalbrookdale Works.

10 Engraving and description of the Iron Bridge.

11 MS. Book. Account of the Horsehay Works, apparently prepared by a Manager in 1876.

12 Photograph. Testing the segments of the Albert Edward Bridge, cast and erected by the Coalbrookdale Co., 1863.

13 1 sh. f'lscap. Cost of materials and of a ton of pig iron at Horsehay, 11 mo. 28th, 1810.

14 1 sh. f'lscap. Make of pigs and profit on Dawley Castle furnace, for year ending 8 mo. 4th, 1811.

15 1 sh. f'scap. Cost of pigs and bars at Horsehay, 1 mo. 12th, 1813.

16 1 sh. crown. Profit on Dawley Castle furnace year ending 7 mo. 31st, 1819.

17 1 sh. crown quarto. Cost of making pig and bar at Horsehay, 6 mo. 1st, 1825.

18 ½ sh. f'lscap. "Experiment to find what quantity of coal it takes to make a ton of coaks." n.d.

19 MS. memo book. Price given for smiths work turning and boring. n.d.

Of the above, Nos. 1 to 5 were lent by Mr. Alfred Darby; Nos. 6 to 12 by Mr. Henry C. Simpson, J.P., and Nos. 13 to 19 by the Secretary, Iron and Steel Institute.

This paper and the following one were discussed together, *see* p. 12.

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The Discoveries of the Darbys of Coalbrookdale

BY

T. S. Ashton, M.A.

(*Read at the Iron and Steel Institute, Westminster, October 8th, 1924.*)

One of the most curious things in the history of technical discovery is the obscurity that has surrounded the origin of the practice of smelting ironstone with mineral fuel; and, even to-day, there is by no means unanimity as to the time and circumstances of the discovery.

In the first place, writers who ought to know better have accepted at its face value the claim of Dud Dudley to have smelted and fined iron with pit-coal as early as 1620. The few facts that are known of Dud Dudley's life show him to have been of an excessively assertive and untrustworthy disposition; and, until evidence from other sources is forthcoming, we shall do well to regard the assertions made in his *Mettallum Martis*, 1665, with at least the same degree of scepticism as we accord to the claims of other courtly projectors of the Stuart period.

In the second place, those who have recognised that Coalbrookdale is the true home of the discovery have left obscure the identity of the discoverer, for whereas Scrivenor attributed the process to the first Abraham Darby in 1713, later writers have followed Dr. John Percy[1] in giving the credit to the second Abraham Darby, and have dated the origin of it variously between 1730 and 1740. It is the object of this note to throw light on this disputed point.

Preserved in the works at Coalbrookdale is a Day Book kept by the first Darby from the very earliest days of the concern. It is clear from entries in this that Abraham Darby had left Bristol for Coalbrookdale in 1708, and that during this year he was busy equipping and reconstituting the newly acquired works; in 1709 he was receiving tools and utensils from the Bristol Ironworks, and was sending thither pig-iron and castings produced at Coalbrookdale.

But the entries of greatest interest are those relating to the purchase of coal from Richard Hartshorne, a master-collier of Little Wenlock. The following (under various dates) in the year 1709, are given by way of example:—

	£	s.	d.
Richard Hartshorn & Co.			
By Cash pd. E. Dorrell pr. theyer order in part for Coles	08	04	06
By Cash pd. Edward Dorall for Coles	05	18	11

[1] *Iron and Steel* (1864), p. 886.

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R. Hartshorn

By Cash paid Dorrall for Getting Coles by theyer order ...	11	19	06
Richard Hartshorn	20	00	00
Pd. Richard Hartshorn pr. William Garbit for Getting Coles	03	19	00
Ditto. pd. Edw. Dorall	05	16	04

For what purpose was this coal obtained? A very small proportion of the whole perhaps for household use and some for a preliminary calcination of the iron-stone. But it appears highly probable that much, if not all, of it was converted into coke and used—whether alone or along with charcoal—in the blast furnace itself. It may be conjectured that the following entry relates to the coking of the fuel for this purpose:—

	£	s.	d.
1709, Aprall 20. By cash pd. for Charcking Coles ...	00	01	03

And though the word "coles" was used at this period for both charcoal and pit coals, it is probably safe to assume that it is the latter that is the subject of yet another entry:—

Lawrence Woling	£	s.	d.
By cash pd. him in part for Coles and Iron Wheald, ye first blast	30	00	00

Hence we have good reason to believe that it was the first Darby, and not his son, to whom the honours should be assigned; and we are confirmed in this belief by the testimony of Abiah Darby, the wife of the second Darby.

Among the family papers of the late Mr. Alfred Darby, of Shrewsbury, is a letter written by this lady to a friend, shortly after the death of her husband, setting forth the main facts of his life and works. Had the second Abraham really been the originator of the coke process his widow would surely have known of it and would have mentioned it in this letter. Not only does she make no claim of this kind, but she expressly attributes the discovery to her husband's father, Abraham Darby, the first;[2] and we have shown grounds for thinking that this was made at least as early as the year 1709.

How then, it may be asked did the confusion arise? In the year 1864 the wife of one of the Darbys gave to Dr. Percy a picturesque account of the discovery, according to which, after a week's vigil at the furnace, the second Abraham Darby succeeded in smelting iron with coke. In view of the evidence submitted above it would appear that the lady had confounded the generations, and most modern writers have been led astray by her story. One, indeed—the writer

[2] The letter is printed *in extenso* in the Author's *Iron and Steel in the Industrial Revolution*, 1924, Appendix E.

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of the articles on the Darbys in the *Dictionary of National Biography*—has attempted to reconcile the two accounts by suggesting that the father discovered the process, but that, on his death, it was forgotten and had to be rediscovered by the son—a most improbable hypothesis.

The absence of contemporary comment on the discovery is to be explained partly by the Quaker reticence of the first Darby, partly by the position he occupied in the iron industry of his day. It is necessary to remember that Abraham Darby was, first and last, a founder; he had studied the process of casting in Holland, had conducted a brass and iron foundry in Bristol, and, with the help of his servant, John Thomas, had devised and patented, 18th April, 1707 [No. 380], the process of "casting iron bellied-pots and other iron bellied ware in sand only without loam or clay." At this time castings were made direct from the blast furnace and there were many defects in the metal; so that it was only rough articles like garden-rollers, grave-slabs, fire-backs, pipes, and pots that could be successfully produced. Hence cast iron played but a subordinate part in industry during the early eighteenth century; fully ninety per cent. of the activities of the ironmasters were given to the production of malleable iron for the use of smiths and metal workers; and since, at first, the coke-smelted pig iron was deemed unsuitable for conversion into bar iron, the few who did know of the new process must have thought it to be of small moment.

This backwardness of the casting branch of the industry, before the days of the Darbys, was due to a physical defect of charcoal; the danger of crushing the charcoal set a limit to the weight of the charge, and the height of the furnace; and the metal left it in a viscous rather than in a fully liquid state. The exact nature of the discovery itself has never been made clear; coke had long been known and used in other industries. It would appear, however, that the clod coal of Shropshire produced a coke peculiarly suited to the smelting of iron, and that the possession of a high furnace and strong bellows[3] enabled Darby to obtain a metal that flowed more freely into the interstices of his moulds, than that drawn from the charcoal furnaces of his day.

During the lifetime of the first Abraham then, the new process was confined to this subordinate foundry branch of the industry. It was the second Abraham Darby who extended the use of coke-smelted pig iron to the production of the more important malleable iron. "About 26 years ago" (wrote his widow in the letter to which reference is made above) "my husband conceived this happy thought—that it might be possible to make bar from pit coal pigs. Upon this he sent some of our pigs to be tryed at the Forges, and that no prejudice might arise against them he did not discover from whence they came, or of what quality they

[3] Among the early entries under the year 1709 are several relating to the blowing apparatus. Thus: 9th. Cr. 12 by Cash pd for ye Larg belos bords.....£15. 00s. 00d.

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were. And a good account being given of their working, he errected Blast furnaces for Pig Iron for Forges. Edward Knight, Esqr., a capital Iron Master, urged my Husband to get a patent, that he might reap the benefit for years of this happy discovery; but he said he would not deprive the public of such an Acquisition which he was satisfyed it would be; and so it has proved, for it soon spread, and many Furnaces both in this Neighbourhood and several other places have been errected for this purpose."

Perhaps it should be made clear that this process of making bar-iron from coke pig-iron was itself carried out with charcoal; it was not until the days of the Cranage brothers that coke was used instead of charcoal for fining.

Let me repeat: the first Darby used coke, in place of charcoal, in the production of castings; his son converted this coke-smelted iron into malleable iron with charcoal; the Cranages and Henry Cort substituted coke for charcoal in this final process. By so doing they broke the last shackle binding the industry to the woodlands, and enabled it to renew its youth on the coalfields of the Midlands, Yorkshire, and South Wales. The work begun by Abraham Darby in 1709 was completed by Henry Cort in 1784.

The Author summarized rather than read his paper and prefaced it by saying that, being interested in Economics, he had been attracted six or seven years ago to the subject of the iron industry. He had not come across a case where one family had dominated an industry for so long as had the Darbys. Coupled with this he had been happy to find that there was now a Society to study the history of technology: hence this paper.

A hearty vote of thanks to the Author was given.

The

DISCUSSION

on this and the preceding paper were taken together.

MR. RHYS JENKINS said that these papers had been presented at the Summer Meeting at Shrewsbury at the same time as his "Sketch of the Industrial History of the Coalbrookdale District."[4] That sketch had been merely a compilation from published sources to give Members a general knowledge of the district. These papers dealt with special aspects of the subject and it had been thought by the Council that they were worthy of more attention than owing to lack of time they had then received. This meeting was the result.

He wished that the evidence about Darby's smelting with coke had been more definite and first hand. Conceivably Darby may have made alterations to the furnace and to the tuyeres but of this we know nothing. Mr. Ashton had, in

[4] *Trans.* vol. IV., p. 102.

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his opinion, touched upon the right reason for the lack of appreciation first shown for the coke-melted iron. It was not good enough for use in the finery to make wrought iron, and there was no other large market at that time for cast iron. There did not exist much inducement for anyone to take up the manufacture even if the knowledge had been widely spread and he did not think it had been kept secret. As a matter of fact, it was forty years before any other ironmaster took it up. By that time there was a rapidly growing demand for cast iron for constructional purposes; henceforward the trade progressed by leaps and bounds.

MR. A. TITLEY mentioned that he had brought with him copies of the documents quoted by Mr. Hall. That there should have been a succession of five generations of one family at Coalbrookdale, all active and important in the industry, was a remarkable record.

MR. FRANK H. FOWLER said that he had been born and bred at Coalbrookdale. He had been present at the funeral of the last Abraham Darby. Mr. Ashton's paper gave the impression that the company's business was declining. This was far from being the case, as they were very busy. The water wheel erected at Coalbrookdale by Abraham Darby II. still existed. Mr. W. G. Norris, the historian of the company, was quite certain that it was the first Darby who had brought in coke smelting in 1709.

MR. H. G. GRAVES mentioned that the letters from Mrs. Darby to Dr. Percy quoted by the latter in *Iron and Steel*, were in the Library of the Institution, whose hospitality they were enjoying. He had been instrumental in securing them.

MR. H. W. DICKINSON remarked that Mr. Ashton had animadverted severely, but not in his opinion unjustly, on Dud Dudley's claims. Some time ago he (the speaker) had tried to find some confirmation of Dud's statements in *Mettallum Martis* as to smelting with pit coal but had quite failed, although much evidence was found to show Dud's litigious spirit.

MR. E. W. HULME corroborated this and gave as an example the patent granted in 1672 to Dudley and Chamberlain for making tin plate when Andrew Yarranton proposed to introduce the manufacture. He had not much doubt the patent was merely a move to prevent the industry being brought in so that Dudley should reap the profits due to importation.

Mr. C. E. Greener, Mr. T. Clarkson and Mr. W. Young also took part in the discussion.

MR. HALL, in replying to the discussion said that what he had got was what was left after Smiles had done. He would like to know from Mr. Ashton what was the date of the letter of Abiah Darby upon which so much turned, because Mr. Norris did not know it. The Cranage brothers made their experiments on the conversion of pig into bar iron in an air furnace at the foundry. What they

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accomplished was in effect puddling on an acid bottom. The result of the supply of charcoal for the furnaces running short was to encourage iron manufacture in the American Colonies. When we began to use coke, that brought the trade to a close.

MR. ASHTON, in reply, said that Dud Dudley made no reference to coke, and if he used coal, as he stated, for refining iron he did something that no one before or since had accomplished. Hence he doubted Dudley's statements.

Charcoal, owing to its friability, limited the height of the furnace. With a greater pressure of blast and using the "clod" coal of Staffordshire a higher furnace could be used and hotter metal obtained. He had the authority of metallurgists for this statement. Such a process was carried out at Bersham by a brother-in-law of Abraham Darby I. in 1721 and Isaac Wilkinson used coke there in the 'thirties of that century.

The date of Mrs. Abiah Darby's letter was unfortunately indeterminable; in the place where the date is usually set the writer had put the year of her husband's death; and all that we know with certainty is that the letter was written sometime after the death of Abraham Darby II. in 1763 and sometime before that of Abiah Darby in 1794. Mr. Norris believed it to have been written about 1775. The first page of the letter is reproduced, by the kindness of Mrs. Muriel Cope Darby. (*See* Plate I.)

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Notes on Original Models of the Eddystone Lighthouses

BY

Thomas Rowatt, M.I.Mech.E.

(Read at Caxton Hall, Westminster, November 12th 1924.)

In the 17th century, Plymouth was a very important port, much used by home-coming merchantmen. But many of these fine ships, laden with valuable cargoes, were wrecked when within sight of land on the Eddystone, a reef lying ten miles south-west of Plymouth and directly in the way of ships coming up the Channel. In those days, the right to erect and maintain a lighthouse was leased by the Crown to an " adventurer " who, in return, was empowered to collect " light dues " from ships, and a very profitable venture it proved in most cases. The erection and maintenance of a light on the Eddystone was not, however, an attractive proposition in those days but, finally, a lease was arranged and Mr. Henry Winstanley built a lighthouse, which was completed in 1698. This building was a fantastic structure and was swept away in the memorable storm of five years later. A new lighthouse was completed in 1709 and lasted till 1755 when it was burnt down. The builder of this was a Mr. Rudyerd who, with the aid of shipwrights, built a very suitable structure of wood designed on the lines of a ship.

The third lighthouse was built by Mr. John Smeaton and the light was first shown in 1768 and continued in use for 114 years. In this building, Smeaton originated what is recognised as the normal design for lighthouses and his building was superseded only because it was unsafe owing to the splitting of the rock on which it was built. Sir James N. Douglass, engineer to the Trinity House, designed the present structure, which has been in use since 1882.

TABLE OF EDDYSTONE LIGHTHOUSES.

Builder	Date	Height	Weight	Illuminant	Candle Power
Winstanley	1696-1698	70-ft.	—	24 candles	67
	1698-1703	100-ft.	—	24 „	67
Rudyerd	1709-1755	70-ft.	270 tons of ballast	24 „	67
Smeaton	1759-1810	100-ft.	1000 tons	24 „	67
	1810-1845			Oil lamps with reflectors	1,125
	1845-1882			Oil lamps with lenses	3,216
Douglass	1882-	133-ft.	4700 tons	Oil lamps with lenses	79,250
				Incandescent oil lamps with lenses	292,500

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Full descriptions of these structures are to be found in the books mentioned in the bibliography at the end of this paper.

Models of Eddystone Lighthouses.

A description will now be given of the various original models, etc., relating to Eddystone lighthouses, which are exhibited in the Royal Scottish Museum, Edinburgh. These models were all presented to the Museum in the year 1859 by the Royal Society of Edinburgh, which had acquired them in 1827 along with the following letter addressed to Sir Walter Scott, Bart., at that time President of the Society:—

"Sir,—I beg leave to present to the Royal Society of Edinburgh a collection of original models made by Mr. Smeaton for the construction of Eddystone lighthouse together with specimens of the Rock and illustrative plans and Drawings. The whole of this collection was presented to the Earl of Morton by Mr. Robert Harcourt Weston, son of the Keeper of the Eddystone Rock, who considered himself under obligation to Lord Morton for the manner in which he had interested himself with regard to Mr. Weston's affairs.

I have the honour to be, Sir,
Your obed. and humble servt.,

Dalmahoy, S. E. Morton."
September 21st, 1827.

It should be remarked that the S. E. Morton who signs this letter was the Countess of Morton, and that Mr. Robert Weston was not keeper of the lighthouse, but the principal lessee.

Considerable light on the origin of the models and drawings is shed by the two following letters, one from Smeaton to Mr. R. Weston, and the other Mr. Weston's reply.

Plymouth, Jan. 25, 1757.

"Sir,—As you express a liking for draughts, models, etc., this is the best time to do them while I am here, and consequently Mr. Jessop not so much engaged, as there is no outwork going on. Your desire of having a draught or model of all the utensils employed in raising the house, I suppose does not extend to the mason's chisels and mallets, but such tools only as have been either contrived on the occasion, or are less generally known.

J. Smeaton."

Jan. 29, 1757.

"Sir,—Though I take great pleasure in contemplating the powers and arts of human invention, and should like to have draughts and models of all

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their designs in my museum; yet I will not now insist on the gimlet or the plane, provided you promise to furnish me at leisure with the more uncommon contrivances. R. WESTON."

Smeaton[1] refers to his first meeting with Mr. Weston when he examined several plans, models and drawings in Mr. Weston's possession, and he goes on to say: "I found, upon further enquiry, that neither the models, drawings or prints were coeval with the structures they were intended to represent, except the print of MR. WINSTANLEY'S Lighthouse published by himself in the year 1699, . . . ; for, as to the models, &c., relative to MR. RUDYERD'S, save a few original drawings, that shewed how some of the courses of stone were laid, . . . they were all of a later date, chiefly since the year 1734."

WINSTANLEY'S LIGHTHOUSE.

The earliest item in the Museum collection is an engraving of Winstanley's lighthouse (1698-1703). The scale of this engraving is approximately ¼ in. to 1 foot, but is far from exact. At the bottom is engraved: "This draught was made and engraved by Henry Winstanley of Littlebury, Gent., and is sold at his Waterworks where is also to be seen at any time ye Model of ye said Building and principal Roomes for sixpence a piece."

It is interesting to note that in addition to the model that he showed "for sixpence a piece," Winstanley also had a model at his house at Littlebury in Essex, and from the fact that it was blown down by the same storm that destroyed the actual lighthouse, I think we may conclude that it was a fairly large model erected in the garden.

RUDYERD'S LIGHTHOUSE.

Some of the most interesting models in the collection refer to Rudyerd's lighthouse, commenced 1706. The courses of the stonework are represented by a series of circular oak boards which average 9 in. diam. x ¼ in. thick. The number of the course represented by each "model" is on the back, and each stone is numbered on the front. On the back of each is a slip of paper with instructions; thus, in the case of course No. 14, "Stand in the centre and read the figures to the right and join No. 19 and 1 together on the middle of No. 1 underneath and observe the figures and characters of the draught." These draughts are mentioned by Smeaton[2] where he refers to a plan of the moorstone courses, "compiled from old working draughts, that appear to have been given out by MR. RUDYERD during the course of the work, for forming and fixing these courses." Unfortunately, some methodical person has evidently scraped the

[1] A Narrative of the building and a description of the construction of the Edystone Lighthouse, 1791, p. 40.

[2] *loc. cit.* p. 23.

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instructions off the back, rewritten them on neat pieces of paper and stuck them on. Authorities on handwriting tell me that the figures on the front of the draughts date from about 1700 while the writing on the paper on the back is about 1800, which points to the probability that the new labels were put on when Mr. Weston cleaned up the models before he gave them to the Earl of Morton.

Of slightly later date is a drawing showing a development of the whole lighthouse. This drawing was made by Mr. John Holland, a master shipwright at Plymouth, who was placed in charge of the upkeep of the structure. Regarding this, Smeaton says[3]: " In this year (*i.e.*, 1734) MR. HOLLAND made a very curious draught of the Lighthouse, in which everyone of the outside upright timbers was distinctly represented; so that every one of them could numerically be referred to; and the places and nature of the scarfings or joinings distinguished." The drawing is a development of the surface of the lighthouse, a method of projection which appears to have been invented by Mr. Holland.

In 1744, a new inspector, Mr. Josias Jessop, quartermaster at Plymouth Dock, was appointed and he made a similar development, which is described by Smeaton as " still more accurate." Unfortunately, neither of these drawings is signed or dated.

There is a drawing of the Rudyerd lighthouse on paper which has turned a reddish-yellow colour and is quite brittle. I would suggest that this drawing has been exposed to smoke for a long period, possibly in one of the rooms of the lighthouse. There are a number of differences between the lighthouse as shown on this drawing and on the drawing in Smeaton's " Narrative."

A beautiful model, 13½ in. high over all, of Rudyerd's lighthouse has the outer wooden casing removable and is fitted with doors and windows of mica. The solid part of the building, which is exposed on removing the outer shell, has the alternate layers of wood and stone marked, the alternate courses of wheel shaped and crossed timbers being clearly shown. The next model shows the solid portion of the tower to a scale of ⅛ in. to 1 ft. (approximately). All the timbers (71) are marked, and every fifth one numbered; the vertical joints in the timbers are also shown. A third model, scale ½ in. to 1 ft., shows principally the positions of the " trees " or iron bolts let into the rock to hold down the lighthouse. These " trees " were evidently planted where the rock was suitable as they were most irregularly spaced. Unfortunately, some well-meaning but mis-directed enthusiast has repainted this model. The other two models, though showing signs of wear, are charmingly painted.

Smeaton says that in 1744 Mr. Josias Jessop, who was at that time superintendent of the lighthouse, made a model of the lighthouse, and I have come to the conclusion that the model made by Jessop is the second one described (to a

[3] *loc. cit.* p. 23.

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scale of ⅛ in. to 1 ft.) as this shows all the timbers and would be the one of most use for keeping a record of repairs carried out on the structure. The complete model appears to be contemporary with the lighthouse.

Smeaton's Lighthouse.

We have now finished with the earlier lighthouses and come to the one built by Smeaton, the bicentenary of whose birth took place in June (1924).

The first item is a sectional drawing of the complete lighthouse to a scale of six feet to one inch, which presents numerous differences from the section to the same scale in Smeaton's book drawn in 1763.

Then there are three engravings similar to the plates in Smeaton's book showing an outside view, and a vertical section of the lighthouse, and a plan and elevation of the lantern. These, however, have no lettering, scales, or titles, and I would suggest that they were proof impressions of the plates before letters, supplied to Smeaton by the engravers.

A plan of the work-yard (scale 1 in. to 10 ft.) is very similar to that shown on plate No. 17 in Smeaton's book. The platform, however, fits more closely the contour of the coast.

There are two series of drawings of the different courses of the tower, one to a scale of ¼ in. to 1 ft., and the other to a scale of ½ in. to 1 ft. Included in the ¼ in. series is a drawing of the steps cut in the rock. On comparing this drawing with that in Smeaton's book the steps in the drawing are seen to be more elaborate, more deeply dove-tailed, and to take less account of the formation of the rock, so one is led to the opinion that this small scale series represents the original draughts made by Smeaton. All these drawings are on the same make of paper and are carefully inked in with Chinese ink. There is, of course, no proof that they are the work of Smeaton's own hands. In fact, the larger scale series is probably the work of Mr. Jessop as, in a letter to Weston, dated 11th January, 1757, Smeaton says, "I enclose Mr. Jessop's copy of the draughts for the seventh and eighth courses, I would only desire that you would not permit the same to be copied."

The model of Smeaton's lighthouse is to a scale of 1/5 in. to 1 ft., and is a beautiful little model made in seven pieces. On the upper surface of the lower pieces the stones are carefully drawn in and coloured to show clearly the differences between the Portland stone and the granite. The platform on which the courses are laid out is shown, as well as another model with a full course of stones, *in situ*. This latter model is mentioned by Smeaton in a letter to Mr. Weston, dated 22nd March, 1757, as follows:—"To-morrow morning will be forwarded to you a box containing Mr. Jessop's model of the platform, and course seven thereon,

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with so much of course eight as is necessary to show to show the relation between the two courses." There is a series of wooden drawing curves, which have been used in making drawings of the lighthouses.

From the somewhat scrappy nature of this collection, I think the conclusion is sound that it represents materials gradually and almost accidentally gathered together during many years; then, when Smeaton learned that Mr. Weston had a museum, he collected all he could and presented them to Mr. Weston. Presumably, the Earl of Morton expressed some interest in the lighthouse, and Mr. Weston went over the collection, cleaned them all up, and presented them to his Lordship.

Whether the models of his Lighthouse are the work of Smeaton, we have no proof. In his book, Smeaton mentions a number of models, and definitely states that he made them himself. " I immediately rough-turned a piece of wood with a small degree tapering above; and leaving matter enough below, I fitted it to the oblique surface of a block of wood, somewhat resembling the sloping surface of the Eddystone Rock." After examining the rock he was able " to make an exact model of the rock, and of the fabric I should ultimately propose upon it. It appeared necessary, as the first step to be taken . . . to construct a *complete Model* of the rock, in the condition I found it; which being done, a second model might *then* be formed, shewing to what the rock was to be reduced, with the manner of applying the work of the building thereto. . . . These models I determined should be the work of *my own hands;* and this, I foresaw, must in its own nature be a work of *Time.*"[4] Smeaton continues,[5] " My models and preparatory matters were now so far brought forward that Tuesday, the 13th of July (*i.e.* 1756), was appointed by the Proprietors for receiving my explanation of what I had to lay before them. I accordingly attended, and submitted to their inspection a complete model of the *house-rock,* in the state in which I had found it; . . . and this was accompanied with another model of the same rock, cut to the intended shape for receiving the building; and therewith connected, a model of the building itself."

A few words may be said about other models of the lighthouse. The Elder Brethren, of Trinity House, purchased, in 1899, a model from Miss A. E. Croft Brooke, who was a descendant of Smeaton; at the same time they purchased from her a diary and a clock, which are almost certainly genuine Smeatonian relics. The model is rather a rough affair, and probably not the one which Smeaton mentions in his book as having been exhibited to the King and other notable people.

A model of the base of Smeaton's lighthouse is in the Leeds Museum. It was obtained from the widow of a man whose father bought it at the Smeaton family sale. It shows the rock and the first six courses of stones.

[4] *loc. cit.* p. 70.
[5] *loc. cit.* p. 71.

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In the life of Smeaton in the " Dictionary of National Biography," it is stated that " A model was made of the entire structure, and is now in the possession of Mr. Oliphant Smeaton, of Edinburgh, but is to become the property of Trinity House." This model was never presented to the Trinity House, and the widow of Oliphant Smeaton declares he gave it to the Institution of Civil Engineers. The model, however, is not in the possession of that body.

A model of the present lighthouse by Douglass is also shown in the Museum. It is made of rock from the reef, and was presented to H.R.H. the Duke of Edinburgh when he opened the lighthouse.

The paper was illustrated by 14 lantern slides, and a number of original drawings and models were exhibited. The drawings and models in the possession of the Royal Scottish Museum are :—

Engraving of Winstanley's lighthouse (1698-1703).
14 Models of the stone courses of Rudyerd's lighthouse.
Model of Rudyerd's lighthouse, $\frac{1}{8}$-inch to 1 foot.
2 Models of parts of Rudyerd's lighthouse.
Contemporary drawing of Rudyerd's lighthouse.
Development drawing of Rudyerd's lighthouse, by Holland, 1734.
Development drawing of Rudyerd's lighthouse, by Jessop, 1744.
Piece of lead from Rudyerd's lighthouse.
3 Engravings of Smeaton's lighthouse.
5 Drawings relating to Smeaton's lighthouse.
9 Drawings of Courses of stonework, $\frac{1}{4}$in = 1ft.
26 Drawings of Courses of stonework, $\frac{1}{2}$in = 1ft.
Model of Smeaton's lighthouse, 1/5in = 1ft.
14 Models of details of lighthouse.
6 Specimens of materials used in construction.
Model of Douglass's lighthouse.

From these the illustrations, Plates II. to IV., have been selected.

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Mr. ROWATT prefaced his remarks on the paper, for he did not read it because an abstract was available to Members at the meeting, by stating that he was indebted to the Director of the Royal Scottish Museum for permission to bring the objects before the Society that evening.

After a vote of thanks to the Author for his paper, and to the Director of the Museum for his kindness in allowing the models to be brought to the meeting, there was an interval to inspect the objects.

DISCUSSION.

Col. E. KITSON CLARK said it was, perhaps, unnecessary to state that Smeaton lived at Whitkirk, nr. Austhorpe, Yorks., where he carried out much of his scientific work, including that on the atmospheric engine. As he, the speaker, came from the same neighbourhood, he was interested in Smeaton, and had been instrumental in securing for the City of Leeds the model of the Eddystone Lighthouse alluded to in the paper. He believed it to be authentic, as it could be traced to the widow of a man who had bought up Smeaton relics. This model he now exhibited, and it was interesting to compare it with the models brought here by Mr. Rowatt. His model showed how Smeaton dealt with the shelving rock on the site of the lighthouse, and made such a sound job that, as a result, the rock gave way sooner than his masonry. There was, also, provision in the stones for lifting eyes.

ENG. CAPTAIN E. C. SMITH said that he had been stationed for a time at Plymouth, and would like to draw attention to the fact that in the Museum there were a number of interesting objects connected with the erection of the lighthouse. He remembered, for instance, that the Curator had shown him a silver medal that was issued to the workmen employed on the lighthouse, to produce in case they were in danger of the press-gang. There was a monument to Zachariah Mudge in St. Andrew's Church, Plymouth. It was said that on the completion of the lighthouse tower, Smeaton and Mudge ascended into the lantern and together sang the Old Hundredth.

SIR GEORGE GREENHILL said the lighthouses on Eddystone and at other positions were erected by people who, for financial consideration, obtained concessions from Trinity House. Winstanley secured the first concession for Eddystone, possibly through influence, for he was clerk-of-works at Audley End, lately the seat of the Earl of Suffolk but at that time in the possession of the King. An engraving of Winstanley's house at Littlehampton is in existence.* The profits accrued, of course, from dues on the shipping which passed up the Channel. Winstanley's lighthouse was swept away by the great gale of 1703, and his was succeeded by that of Rudyerd, who was a linendraper in Cheapside. His lighthouse was burned down. How Smeaton came to be called in, he did not know.

MR. A. TITLEY said there could not be much doubt that the models before

* This is the engraving which was on exhibition. *See supra* p. 21.

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them that evening were made by Smeaton's own hands, for he mentions in his *Reports* that he altered his designs as he went. He would be interested to know if any of the models corresponded with the curves shown in the *Reports*.

MR. L. ST. L. PENDRED mentioned that Smeaton's tower started with a curve from the base upwards while Douglass's tower was cylindrical for a short height and then the curve began. Winstanley's lighthouse was said to have cost £8,000 but, owing to its short life, he did not recover the capital expenditure. Rudyerd's lighthouse cost £10,000 but as it lasted nearly 50 years, it proved most profitable. Smeaton's lighthouse cost £16,000 and was done most economically. He (the speaker) would like to know more about Rudyerd as he must have been a remarkable man.

MR. ROWATT, replying to the discussion, said the Trinity House model alluded to in the paper shows the tree trunk idea and is rather rough so that he was inclined to think that it was the original. When the Rudyerd lighthouse was burnt down, the lessees faced the cost of re-construction without any help from the Trinity House except to get their lease extended. Smeaton was employed by them on the recommendation of the Royal Society, but he made it clear, as a condition of taking up the work, that he would not be interefered with in his design.

Rudyerd, as far as he knew, had no architectural or engineering knowledge, but he had wisdom enough to employ shipwrights, and the design of his light-house was obviously borrowed from that of a man-o'-war of the period. Smeaton, however, broke away from this construction and his credit is that he struck out an altogether new path which has been followed by his successors.

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The Early History of the Cylinder Boring Machine.

BY

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(*Read at Prince Henry's Room, Fleet Street, December 17th, 1924.*)

A complete history of machine tools has yet to be written, although the development of certain tools, such as the lathe, has come under the notice of the engineering historian. One machine of importance, which has hitherto received scant attention, is the cylinder boring machine, which is not only notable as being the first large machine tool in which the copying principle was carried out, but also because of the part it played in contributing to the development of the steam engine.

The earliest form of boring machine was merely a development of the hand worked auger—as illustrated by Agricola and other writers—used for boring wooden water pipes or pump trees, the auger being driven by a horse gear or water wheel, while the tree was mounted on a wheeled truck which could be drawn towards the auger by a rope and hand winch. When brass and iron pumps and also guns were introduced, the same mechanism was used, but the auger was replaced by boring bits suitable for the metals to be operated upon. As the holes required were comparatively small, simple D-bits were probably the cutters generally used. It is obvious that with such machines a perfectly straight bore could not be expected even though the hole was truly circular at any one point.

With the advent of the Newcomen atmospheric engine in 1712, larger cylinders were required, and it appears that at first these were unbored, but were simply smoothed inside by grinding or filing. Weighted soft packing and a water seal were relied on to keep the pistons sufficiently air-tight, but the rapid wear and consequent leakage probably soon led to attempts being made to bore the cylinders with the same machines as had been used for the smaller articles. This, however, involved the use of a boring head as large as the cylinder and having one or more cutters set round its periphery. Such a heavy head, mounted on the end of a comparatively small bar, necessarily tended to cut mainly on the lower part of the cylinder, while possibly barely touching the upper part, and as it depended for its guidance solely on the cylinder casting itself, the resulting bore was usually neither circular nor straight. To ensure cleaning up the whole interior surface, it became the practice to bore a cylinder in four settings, turning it through 90 deg. at each setting, but the result was no more accurate.

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Perhaps the best recorded example of such a cylinder boring mill is the one erected by John Smeaton at Carron Ironworks in 1769, and which is described and illustrated in his *Reports*.[1] The imperfections of this machine were recognised, and Smeaton himself, when asked to improve it, could only suggest supporting the outer end of the boring bar on a four-wheeled carriage which travelled along the bottom of the cylinder; this, while taking the weight of the boring head, could not much improve the straightness or circularity of the bore.

The next and greatest step towards an accurate boring machine is attributed to John Wilkinson, of Bersham Ironworks, in or about 1775. His invention consisted in mounting a long stiff cylindrical bar in bearings at each end, and fitting it with a cutter head which could be traversed along the bar from end to end. The method gave at once a truly circular and straight bore, and it may be said that its invention removed from Watt's path what was perhaps the greatest obstacle he encountered in his endeavours to make his first steam engine a success, namely, the difficulty in obtaining a cylinder bored with sufficient truth.

When Watt removed from Glasgow to Birmingham in May, 1774, he brought with him his imperfect cylinder of hammered tin, which was found useless and abandoned early in 1775. By April of that year he had obtained a new cast iron cylinder, presumably bored on Wilkinson's new machine, and this proved satisfactory. Watt, writing to Smeaton in April, 1776, said, " Mr. Wilkinson has improved the art of boring cylinders so that I promise upon a 72 in. cylinder being not further from absolute truth than the thickness of a thin sixpence in the worst part." Boulton also, writing to Carron Ironworks in the same year, said, " Mr. Wilkinson has bored us several cylinders almost without error, that of 50 in. diameter, which we put up at Tipton, does not err the thickness of an old shilling at any part, so that you must either improve your method of boring or we must furnish the cylinder to you."

Wilkinson did not take out a patent for his cylinder boring machine, although his gun boring patent 1774 is sometimes confused with it. Rival ironfounders, recognising its value, soon copied it, and from the Boulton and Watt correspondence we learn that, in May, 1780, a boring mill on Wilkinson's plan was being put up at Coalbrookdale. In the following year Wilkinson complained to Boulton that his mill had been copied by Banks and Onions of Benthall, and Watt, writing to Boulton on July 23rd, 1781, said, " As to Wilkinson's complaint of Onion's boring mill, he ought to have taken a patent or kept it secret." In August, 1781, one of Boulton and Watt's erectors at Ketley was asked to inquire if Onions's boring mill was at work, and later in the same month it is intimated that this mill was nearly completed.

In a letter of January 9th, 1782, Watts tells Boulton that " Hornblowers are

[1] *Reports*, Vol. I., p. 376.

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erecting a Wilkinsonian boreing mill for their cylinders." In 1792 the Eagle Foundry at Birmingham put in a mill.

It has been suggested that Wilkinson's patent No. 1863, of 1774, for a new method of boring guns, although very clearly specified, could have been stretched to cover the cylinder boring machine, which was quite different in principle. The fact that this patent was revoked in 1779, and that it was not until 1780 that the Coalbrookdale mill was erected, might suggest that Wilkinson's rivals did not risk copying his machine while that patent was in force. On the other hand, Watt's letter of 1781, already quoted, shows that, in his opinion, Wilkinson's invention of the cylinder boring machine could and might have been patented.

Gregory's *Mechanics*, published in 1806, attributes the improved machine to Wilkinson, and describes its chief feature, but nothing appeared to be known of the details of it until recently, when the occurrence of the Watt Centenary in 1919, led to the discovery, amongst the early Watt drawings at Birmingham, of two drawings of boring machines of great interest. Copies of these drawings are now in the Science Museum, South Kensington.

The more valuable of the two is a drawing entitled " Drawing of the Bersham Boreing Mill by Jno. Gilpin "; it is undated but must have been made prior to 1795, as the Bersham works were closed in that year. It seems probable that the drawing was obtained by Boulton and Watt as a basis upon which to design a boring machine for the new Soho Foundry in course of erection in 1795, or it may have been brought back some years earlier by James Watt or his son after one of their visits to Bersham. It is not known who " Jno. Gilpin " was, but a Gilbert Gilpin was Wilkinson's clerk or manager at Broseley up to 1786, so that John Gilpin may have been a relative of the latter.

The drawing is to a scale of 1 : 36 and is coloured; a copy of it is shown in Plate V. It will be seen that the general lay-out is similar to the Smeaton type of mill in that a water-wheel drives, through spur gearing, two parallel horizontal axes on each side of it. In fact, the mill has the appearance of being a modification of an earlier one, as there exist on it a travelling carriage and hauling winch such as were used for mounting the cylinders on those mills. The mill has two boring bars, a large one 12 in. diameter and 15 ft. long, and a smaller one opposite to it 10 in. diameter and 14 ft. long; each is shown with a cylinder fixed in position by chains, the larger one being 45 in. diameter by 11.25 ft. long, and the smaller one 27 in. diameter by 6.75 ft. long. The remarkable point about these bars is that they are hollow, a feature which had been hitherto, but erroneously, attributed to Wm. Murdock, and the cutter heads are moved by central rack bars which pass down inside the boring bars, where they are connected with the heads through slots running the whole length of the bars.

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The racks are prevented from rotating by guided cross-heads at their outer ends, and the feed motion is given by weighted levers on the axes of pinions engaging with the racks, that being the common method of feeding the tools in the cannon boring mills of the period. Adjacent to the larger bar is what appears to be a facing lathe with a large hollow mandrel and a back centre; this may have been used for turning cylinder covers, pistons or boring heads. Opposite to this is a lathe with a long wooden bed and loose headstock, apparently for turning such objects as piston-rods or even the boring bars, but no tool rest is shown. Incidentally it should be noted that the gearing on one side of the water-wheel has stepped teeth.

The chief constructional feature of the boring machine, after having established the Wilkinson principle of guiding the cutter head along a straight bar, is the method of feeding the head, and the development of this has been somewhat obscure. This Bersham drawing establishes the fact that Wilkinson's bars originally had the rack feed, and it will be interesting subsequently to try and trace the introduction of the screw and positive feed as ultimately adopted. Not only does the drawing show the construction of Wilkinson's machines, but it lends support to the tradition that an old boring bar now in the Science Museum, South Kensington, is, in fact, an original Bersham bar.

The bar in question is 15 ft. long and 11.875 in. diameter, and was presented to the Museum in 1913 by the Hydraulic Engineering Company, of Chester, through the instrumentality of the late Mr. E. B. Ellington. With it came the following statement as to its history, made in 1878 by Mr. Ellington's partner, Mr. Bryan Johnson: "An iron foundry at Bersham, near Wrexham, carried on, I believe, by Mr. Wilkinson, was at that time capable of making the largest castings then asked for. Messrs. Boulton and Watt used to get the cylinders for their earlier pumping engines made at Bersham, and the boring bar in question was made there and employed in boring these cylinders. When the Foundry was given up, the bar was purchased by Messrs. Rigby, Engineers of Hawarden and Sandycroft. By them the bar was turned up again and fitted with a new screw, the original boring head being bushed. Mr. Howell, Messrs. Rigby's manager, who gave me these particulars, said that on turning the bar the metal was found to be of very first class quality, the cuttings being quite like wrought iron. When Messrs. Rigby gave up business, about the year 1854, I purchased the bar at the sale of their plant."

The dimensions of this bar—see Plate V.—agree very closely with those of the large bar shown on the Bersham drawing, but it is now fitted with a screw operated by spur gearing which rotates it at a slightly lower speed than the bar. When the screw feed was first fitted to this bar is not exactly known, but as the Bersham works closed down in September, 1795, Messrs. Rigby must have

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acquired it at that time. Mr. Johnson's statement that it was turned up and a new screw fitted by Messrs. Rigby seems to imply that the new screw replaced an older one; if that were so, it would mean that the old screw was fitted at Bersham, and had been in use long enough to become worn out. In that case, it is to be expected that the screw feed would have been known to other makers before 1795, which does not appear to have been the case, as we shall see later. It seems, therefore, more probable that Mr. Johnson meant by his statement that the first screw was fitted by Messrs. Rigby after the bar was acquired by them.

This bar is now arranged for driving by a large carrier keyed on one end of the bar, but beyond this there appears to have been a square end, such as would have carried a spur wheel—as shown on the Bersham drawing. This, however, has been cut off and the end of the bar bored to receive the tail of the screw. The other end of the bar originally terminated about an inch beyond the bearing, and the bore, which is 4 in. diameter, was carried through to the end. An extension piece has been fitted to this end to provide a bearing for the feed screw and space for mounting the spur wheel which rotates it. A hole 2 in. diameter passes transversely through the bar at the point where the slot is enlarged for the insertion of the nut. A hole, such as this, is not required for the nut, but was necessary for pinning the end of the rack bar, where it passed through the socket attached to the boring head, or rather to the sleeve on which the cutter heads were mounted, and the nut, about 6 in. long, is bolted to a large key, which fits the slot in the bar and engages with a groove in the sleeve. The key is secured by a screw and a cotter, the drive being taken by a head on the key. The bar is now mounted on two cast iron pedestal bearings, having lower brasses only, but these are probably more modern. The present screw is 2.5 in. diameter, and has a right-hand square thread of two turns per inch. The gearing consists of a 60-tooth wheel on the end of the bar engaging a 63-tooth wheel revolving on a pin projecting from the pedestal. Fixed to the latter wheel is a 60-tooth wheel gearing with a 63-tooth wheel running loose on the plain end of the screw, and having dogs projecting from its outer face. This wheel can be connected with the screw by a sliding hand wheel keyed to the screw and provided with corresponding clutch dogs. For every turn of the bar the screw rotates about one-eleventh of a turn relatively backwards, giving a feed of 0.046 in.

There is, then, a strong probability, if not certainty, that this bar, but not its feed screw, is one of the original Bersham bars used by Wilkinson for boring Watt's engine cylinders between the years 1775 and 1795.

When Boulton and Watt's Soho Foundry was under construction in 1795, naturally one of the most important tools required would be a cylinder boring machine, and it may be supposed that the Soho machine would be based on Wilkinson's. The question of its design had evidently been under consideration

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by Watt and Boulton, for on June 8th, 1795, James Watt, jun., writing to Boulton, says: "Inclosed you have Mr. Peter Ewart's plan for perpendicular boring, which I address to you as the advocate of that mode of operating. When you and my father have come to a decision upon the subject, I shall be glad to know it, that we may immediately be proceeding with the boring rod and other essential parts." Fortunately, the drawing mentioned in this letter has been preserved, and is the second of the two found in the Birmingham collection. It bears the date of the letter, written in the handwriting of James Watt, jun.; a copy of it is shown by Plate VI. The description on the drawing is as follows: "A. a shaft from the engine. The shaft B. is inclined that the wheel C. may be out of the way. The spur wheel D. to be wedged upon the rod E. F. a floor over the wheel. When a cylinder is to be put on, the sliding pieces G. must be put into such of the holes H. as are fittest for the length of the cylinder. The piece I. (having the spindle K. fixt upon it) must be removed and the cylinder lowered down till the top flanch rests upon the bearers L. The sliding pieces G. being then drawn out and the iron pins N. being put in, the cyl'r must be adjusted to the rod by the screws O. The bearers L. being fastened by the wedges P., the cyl'r is kept from turning round by the wedges Q. After the cylinder is bored, the top and bottom flanches may be turned by cutters fixed in the same tool by which the cylinder was bored."

The Ewart mill is a vertical one, as explained in J. Watt jun.'s letter, but differs from Wilkinson's in that the boring bar is solid with a keyway along it, and that the feed is obtained by two external rack bars connected with a loose ring on the cutter head and operated by pinions. The means by which the pinions were to be turned is not shown. The bar is 12 in. diameter and 14.5 ft. long, and is shown boring a cylinder 28 in. diameter by 7.25 ft. long. The whole machine is contained in a masonry pit, and its framework is entirely of wood. It seems to have been actually constructed, because in a later letter J. Watt jun., mentions the bar as having been made at Bersham. In 1895, when the Soho Foundry was dismantled, there existed several early horizontal screw-feed boring bars, and a large vertical mill, which was built much later, but by that time there was presumably no trace left of this pit mill, so that how long it remained in use is uncertain.[2]

Neither Watt nor Murdock took out any patents for actual cylinder boring machines, but in 1802 we find that a certain Michael Billingsley, of Bowling Ironworks, near Bradford, patented a vertical boring machine which was practically an exact copy of Peter Ewart's machine, except that the framing was of iron instead of wood. The cutter head was moved by two external racks, as

[2] It is clear from Mr. Rhys Jenkins' remarks during the discussion, *see* p. 37, that Ewart's mill was not constructed.

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in Ewart's machine, but the pinions were rotated through gearing by a belt passing round the boring bar itself. Billingsley claimed the invention of the vertical arrangement, and also this form of positive automatic feed, stating that the latter is superior to the hand lever feed. This kind of feed motion may have been employed on Ewart's mill, as it would seem to be a natural improvement on the weighted lever feed. There is a suggestion of something of the kind in a letter from Watt to Boulton, dated May 16th, 1797, where he says: "Boring by means of a strap succeeds extremely well, to make matters complete will require however an expensive alteration." Of course, this statement might also be interpreted to refer to the substitution of a belt for the gearing used to drive the bar itself. There is no suggestion of the screw feed being in use at the date of Billingsley's patent.

William Murdock returned to Soho from Cornwall in 1798, and in 1799 he patented the worm and worm wheel method of driving boring mills. His specification drawing shows the driving end of a horizontal machine, but does not show the bar itself. He states the size of a worm that he had been using, which was 16 in. diameter, three threads, 6 in. pitch, and its bearings are shown mounted on masonry piers, as were those of a dismantled 16 in. hollow bar, which lay at Soho in 1895, and was then said to be the first ever made there nearly 100 years previously, and credited to William Murdock. From this it is evident that Murdock had made a horizontal cylinder-boring machine at Soho in 1799, but we are unable to say with certainty that he introduced the screw feed at that time.

The earliest instance we are able to trace of the screw feed in a boring mill is on a Swedish gun mill, illustrated in the *Memoirs* of the Stockholm Academy for 1782. This was a mill of the kind patented by Wilkinson in 1774, that is, one in which the object to be bored rotates while the non-rotating boring tool is fed up to it. The usual feed mechanism on those mills was either levers or rack and pinion, but in this example a screw about half as long as the gun bore was used. The screw was prevented from rotating and passed through a nut turned by a hand wheel, its point bearing against the back end of the boring tool. On reaching the end of its travel, the screw was withdrawn and a distance piece inserted between it and the tool.

Amongst the tools at Soho when the works were sold in 1895 there was a horizontal screw feed boring bar, 11.875 in. diameter and 14 ft. 4 in. long, said to have been made in Murdock's time. This had a hand-cut screw passing through a nut fixed to the cutter head, but it did not pass down the centre of the bar, but lay in a groove close to the surface. The screw was rotated by an epicyclic train from a fixed pinion mounted on a bracket beyond the end of the bar. Holtzapffel, in the second volume of his book on *Turning*, published in 1856, gives a sketch of the end of a boring bar with a screw lying close to the bar,

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but not in a groove, and shows a large spur wheel on the screw engaging with a pinion mounted on an axis coincident with that of the bar. Such a construction would involve a very large journal to embrace the screw bearing, and it would be an improvement to put the screw in the keyway along the bar, as was done on the Soho bar mentioned above. Holtzapffel said that he was told by Mr. John Taylor, F.R.S., that the machine was invented by George Wright, when in the employ of Boulton and Watt at Birmingham. A man named Wright is mentioned as one of the early Soho mechanics, but when he was employed there is not known. Holtzapffel's sketch, however, represents a machine boring the semi-circular casing for a D valve, so that its date would be later than 1800. The large vertical boring bar at Soho, said to have been erected between 1860 and 1870, had the same screw arrangement, which by that time had become the standard form.

It seems, then, that the early Soho bars were sometimes hollow, but their screws were fitted in shallow grooves, which also served as keyways for the cutter heads. There is no definite evidence that they existed as early as 1800, as tradition asserts, but if Murdock or Wright had actually introduced the screw by that date its use was probably kept as secret as possible. Joshua Field, as noted in his *Diary* in 1821, saw one large and four small boring bars at Soho Foundry, but did not describe them. The statement that the screws were hand-cut indicates that they were made before there were any large screw-cutting lathes, and William Buckle, who became manager of the Soho Foundry in 1824 or 1825, is credited with making the first large screw lathe there. The cutting of these long screws by hand was evidently a special art practised at Birmingham about the end of the eighteenth century, and the available evidence tends to support the belief that the ultimate form of the screw-feed boring bar originated there.

It has been supposed that such screws were laboriously cut entirely by chisel and hammer, and finished with a file, but this is not strictly correct, as will be seen from the following description of the method used in cutting a large screw, extracted from T. Gill's *Technological and Microscopic Repository* of 1830:—"About 40 years since (*i.e.*, in 1790) an ingenious smith at Birmingham named Anthony Robinson was employed by the late Matthew Boulton to make him a large wrought iron screw for a press, of about 6 in. diameter and 7 ft. long. The bar having been turned, a long parallel strip of paper was fitted to it, its edges exactly meeting on a line parallel with the axis. The paper was then removed and across it were drawn sloping lines to form a triple thread. The paper was then cemented to the cylinder, and the lines pricked out with a punch. After removing the paper, the punch marks were joined up by a file edge so as to form helical lines. The metal between the pairs of lines was then cut away by a chisel until sufficient depth was obtained to form a lead. A long typemetal nut was then cast in an iron box placed round the screw which was erected vertically

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so as to be rotated in the nut by six men working on capstan handles fixed to the screw. The nut box was fixed to a beam and adjustable cutters were mounted on it, by means of which the screw was soon brought to proper shape."

It is obvious that by this method much labour was saved and a better screw produced than if cut entirely by chisel and hammer; the long nut tended to smooth out the errors in the preliminary cut, the marks of which would probably be entirely removed.

If the screw feed was actually introduced at Soho about the year 1800, the method of its application must have been kept very secret, as cylinder boring machines were made by other engine builders at about the same period or shortly afterwards, which, although embodying a screw feed, applied the screw in a variety of different ways.

After the date of Billingsley's patent, the Author has found no contemporary illustration of a cylinder boring machine until 1817, when John Farey made a drawing of one of Matthew Murray's machines for the sixth edition of the *Encyclopædia Britannica*. This is shown in Plate VI. The machine has a solid bar with two longitudinal grooves along opposite sides of it, and in each of these grooves there is laid a rack bar with its teeth facing inwards. The racks are fixed to the sliding cutter head, and revolve with the bar, while the rack teeth, which virtually form a long nut, engage, beyond the end of the boring bar, with a short screw mounted on a central spindle. This spindle extends rearwards so as to allow the racks to attain the full travel of the head, and its outer end is connected by gearing and a long upper shaft with a spur wheel mounted on the end of the boring bar. The bar is 8.5 in. diameter and 9 ft. long, and is shown boring a cylinder 17 in. diameter by 5 ft. long. As Murray started his engine factory at Leeds in 1795, this machine may have been constructed then, or shortly afterwards. Farey, writing in 1816, said that Murray had two machines for boring cylinders. He is also known to have been making boring machines for export as early at 1806.

In 1818, Farey made, for Rees's *Cyclopedia*, a drawing of Mr. John Dixon's boring machine used at the Falcon Iron Foundry, Maid-lane, Southwark. As he also illustrated a steam engine at the same factory for Nicholson's *British Encyclopedia* in 1808, it is probable that this machine existed at that date. A copy of Farey's drawing is shown in Plate VII. It will be seen that the machine had the Wilkinson hollow bar, but had two slots on opposite sides. It had a central screw of the full length of the bar, but instead of being rotated and passing through a nut on the cutter head, it was loosely pinned to the head, prevented from rotating by a crosshead on its outer end, and passed through a nut which was mounted on a fixed post and turned by a hand wheel. The bar was 9 in. diameter and 9.5ft. long, and is shown boring a cylinder 19in. diameter by 5ft. long.

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Wilkinson's rack feed machine and both Murray's and Dixon's machines were practically twice as long as their bars. Murray's, however, was superior in that it had a positive automatic feed, while Dixon's had only a hand feed.

The next machine to be noted is of another design, also attributed, by later writers, to Matthew Murray. In this the cutter head is fixed to the middle of a very long boring bar, which rotates and at the same time slides through its two bearings by the agency of a screw and nut. Although brief descriptions of this form of machine are to be found in English works, the earliest complete drawing of one, extracted from a French publication, was given in Gill's *Technological Repository* for 1822. The machine described was in use at the engine works at Chaillot belonging to M. Périer, and was said to be the machine which the English mechanics then used for the purpose of boring cylinders. It is stated that only two such machines existed in France, the one at Chaillot and another at St. Quentin. It is highly probable that both these machines had been made by Murray, who was one of the principal machine tool makers of the period.

The French writer evidently appreciated the positive automatic feed, as he stated that "the movement of the boring head being uniformly continued, the result is that the work is more quickly performed, and is more perfect than when done on the old machines where one was obliged to raise, from time to time, the weight which impelled the boring head."

A much better drawing of the Chaillot machine was published, however, in the *Bulletin de la Société d'Encouragement* in 1823, and a copy of this is shown in Plate VII. This machine had a boring bar 5.5 in. diameter and 13.25 ft. long. Its two bearings were 6 ft. 4 in. apart, and the maximum travel of the head was 5 ft. The boring head was keyed to the middle of the bar and the whole bar was moved endwise through its two bearings and through the driving wheel, which was mounted close up to one of the bearings and the key of which fitted a slot cut along the bar. A screw, 1.75 in. diameter and 6 ft. long, with a pitch of 0.5 in., was fixed to the end of the bar and had its outer end supported by a nut which could turn in a fixed bearing. The nut had a gear wheel with thirty-eight teeth fixed in it, which engaged with a 36-tooth wheel fixed to the end of a square countershaft, along which could slide a second wheel with thirty-eight teeth constantly engaged with a wheel of thirty-six teeth fixed on the end of the boring bar. The sliding wheel was pushed along by a flange on one side of it. The bar was driven from a vee-grooved stepped pulley through double reduction gearing. As the bar rotated, the feed gearing caused the nut to rotate relatively backward at about one-eighth of the speed, so giving a feed of 0.065 in. per revolution of the bar. The bar being drawn through the driving wheel, held the latter in position against the bearing. A cylinder 20.5 in. diameter and 4 ft. long

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is shown on the machine. It is supported on adjustable vee blocks, to which it is secured by chains with tightening screws.

This form of machine no doubt produced good work, but certainly appears to be clumsy as its overall length was 22 ft. for an effective travel of only 5 ft. The construction was probably only used for the smaller machines, but curiously enough it seems to have been better known than the other contemporary screw-feed machines. This is possibly due to the fact that machines of this form were made for sale and export, and not merely by an engine maker for use in his own works. Simon Goodrich had a small machine of this type, no doubt made by Murray, in Portsmouth Dockyard in 1813, and he gives a rough sketch of it in his *Journal*.

The first quarter of the nineteenth century has thus been searched without discovering a contemporary description or illustration of the short, compact form of screw-feed boring bar which, as we have already seen, tradition asserts to have been invented by William Murdock at Soho about the year 1800. It is very difficult to understand how, if such machines existed at that time, they could have been kept secret for over twenty-five years, seeing that Boulton and Watt's works were the training ground of numbers of engineers who subsequently distributed themselves over the country, and must have carried with them a knowledge of the machines employed at Soho.

The writer is, however, not aware of any mention or description of such a machine until 1829, and here, again, we are indebted to a foreign source for the information. In 1828, two French engineers, MM. Coste and Perdonnet, visited England to study the mines, ironworks and railways of the country, and published an account of their observations in the *Annales des Mines* for 1829. They described the machinery used in ironfoundries and engine factories, including cylinder boring machines. At several places they found only the Wilkinson type of machine in use, either with the ancient rack, lever and weight feed, or else improved by the rack pinion being positively driven by the machine. They also saw Billingsley's vertical rack-feed machine at Bowling, working just as it was in 1802.

At the works of Messrs. R. Stephenson and Co., at Newcastle, they noticed a machine with a hollow bar, sliding head and central screw of the Dixon type, but the account does not say whether the feed was automatic. At Fairbairn's works at Manchester was a small boring lathe, in which the cutter head was fixed on a bar placed between the lathe centres, while the cylinder was mounted on a sliding table moved by a leading screw in the bed.

At an unnamed works at Glasgow, however, they saw a machine with a solid bar about 12 in. diameter, along which the boring head was moved by two screws, about 1 in. diameter, sunk in grooves 1.5 in. square, cut along the bar. The

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screws carried toothed pinions on their ends, which engaged with an internally toothed ring mounted on one of the pedestals that supported the bar. When boring, this annular wheel was rotated by external teeth and gear wheels at a suitable speed for the feed required. The reporters were unable to obtain a drawing of the machine, and so gave a diagrammatic sketch only, but it is the earliest illustration of the type known to the author and it also shows the duplicate screw arrangement which was afterwards much used. Curiously enough, the French engineers make no mention of having visited Murray's works at Leeds or the Soho Foundry at Birmingham.

Shortly after this time, Hebert, in his *Engineer's and Mechanic's Encyclopædia*, published in 1835, gave a description of the second type of Murray's machine—*see* Plate VII.—and also described and illustrated a large iron-framed vertical boring machine, which was said to have been erected in an extensive engineering establishment, and which he thought had not appeared in print before. The woodcut is a poor one and not worthy of reproduction. It shows a machine with a solid bar and a single feed screw lying in a groove. The feed motion was derived from the rotation of the bar by a fixed bevel wheel at the top of the frame, through epicyclic gearing, consisting of a bevel pinion, worm and worm wheel.

For a good illustration, however, we have to wait until 1841, when Robertson Buchanan published the third edition of his *Treatise on Millwork and Other Machinery*. In this he gave drawings of three large vertical boring machines, and pointed out the advantages of the vertical type for boring large cylinders, viz., the avoidance of distortion of the cylinder or boring bar under its own weight, the gravitational clearance of the cuttings, and the smaller floor space occupied. He also claimed that less power was required to drive them. Plate VIII. shows a machine by Nasmyth and Gaskell, of Manchester. This had a solid bar, 16 in. diameter, with automatic screw feed, the screw being housed in a slot in the bar and operated by epicyclic spur gearing and a fixed pinion at the upper end of the bar. In this case the machine was placed in a corner of the shop, the walls serving as the frame, and the top end of the bar having its pivot mounted on a diagonally placed cast iron girder. The driving spur wheel below was driven by a worm, and the machine is shown boring a cylinder 73 in. diameter.

The other two machines illustrated by Buchanan were not, however, normal screw-feed machines. One by Nasmyth and Gaskell had a central rack with automatic feed gear mounted on the top of the bar, and deriving its motion from a fixed screw ring. This machine was made for boring the 10 ft. diameter cylinders for the Great Western Navigation Company's vessel "Mammoth,"[3] then

[3] The name of this vessel was changed before launching in 1843 to "Great Britain."

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under construction at Bristol. The other machine, by Benjamin Hick and Son, of Bolton, had the Murray double-rack and short screw arrangement, similar to that shown in Plate VI.

It would appear, then, that by about 1830 the cylinder-boring machine had arrived at its final form, although even then that form was not widely known. Since then practically no change has been made in it, except for variations in the arrangement of the feed gear. The horizontal position was adopted for small machines and the vertical position for the large machines.

It is clear that to Wilkinson is due the main principle of the machine, but we cannot be certain as to who introduced the automatic screw feed.[4] The writer is inclined to doubt the Murdock tradition, which is only supported by our knowledge that the necessary screws could have been made at Birmingham at the time, while the fact that the old Soho bars were hollow, inclines one to think that they had originally the central rack feed of Wilkinson, and that they were subsequently fitted with Wright's screw arrangement.

There the matter must rest until further evidence comes to light. It is rather curious to find that over the whole period 1775 to 1840 only one patent ,that of Billingsley in 1802, was taken out for cylinder boring machines.

The paper was illustrated by seven line drawings prepared by the Author. From these blocks have been made for the illustrations, Plates V. to VIII.[5]

The President said the paper was of great value and reflected much credit upon the Author's research. He moved a vote of thanks, which was heartily accorded.

DISCUSSION.

MR. E. W. HULME mentioned that Wilkinson's patent[6] for the boring machine was challenged by the Board of Ordnance on the ground that the invention was not novel, three Dutchmen having used similar machines previously for gun boring. Wilkinson did nothing in the matter until the Board applied to the Privy Council, when Wilkinson filed an injunction in the Court of Chancery. As he did not proceed with the injunction, the Board obtained a revocation of the patent. Wilkinson did not take legal action, which goes to show that he concluded that he could not sustain the validity of the patent.

THE PRESIDENT stated that Wilkinson's machine was for boring guns from the solid and had nothing to do with cylinders. The fact was that the Board of Ordnance had had brass guns and wanted to make contracts with makers of iron ones. It was his belief that bored cylinders were used for the early Newcomen

[4] During the discussion, Mr. Rhys Jenkins showed that James Watt, Jnr., saw the "screw feed" in Murray's works in 1802, so that its invention was probably due to the latter.

[5] We are indebted for the loan of these blocks to the Editor of *The Engineer*.—(Ed.)

[6] A.D. 1774 (No.1063) "A New Method of Casting and Boring Iron Guns or Cannon."

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engines and that the method was brought into use at Coalbrookdale. In an Appendix to Mr. Davey's paper[7] on the Newcomen engine, Mr. W. G. Norris quoted from a list of parts of engines cast at Coalbrookdale commencing in 1724 and in it appears under that date a charge of 32s. 6d. per cwt. for cylinders; in the same list in 1728, " 3 pipes bored " are mentioned but not bored cylinders. It is quite possible that Wilkinson may have been working on a machine for smoothing cylinders by a rubbing block. In 1734 Desaguliers mentions[8] that " there are Workmen that can bore them " (*i.e.*, cast iron cylinders) " very smooth."

He was able to assure the Author that Ewart's vertical boring mill at Soho Foundry was never made. At the time this mill was projected, Murdock was in Cornwall and Watt decided he would not have a vertical mill; consequently a horizontal one was made. When Murdock returned from Cornwall in 1798, a boring bar was brought from Lowmoor. The President regretted that he was unable to throw much light on the screw feed. When James Watt, junr., inspected Matthew Murray's works at Leeds in 1802 he wrote to Matthew R. Boulton as follows[9]: " the cutter head is pushed forward along the boring rod by an endless screw. We must adopt some similar contrivance."

MR. G. F. TYAS mentioned a later vertical machine with a screw feed. The boring bar was able to bore cylinders up to 108 inches in diameter. At the Leeds Bridge Foundry in 1808, mention is made of a large iron boring bar worked by an engine and two boilers. The cylinder boring machine at the Airedale Foundry was similar to that of Boulton and Watt. It had a screw feed arrangement worked by a star wheel.

MR. A. TITLEY mentioned that a vertical mill was installed at Soho Foundry in West's time.

MR. A. LEGROS quoted Desaguliers in 1734 as having dissuaded his readers from having cast iron cylinders. " Some people make use of Cast Iron Cylinders for their Fire Engines; but I would advise nobody to have them."

MR. L. ST. L. PENDRED said that a reliable history of the lathe and the boring mill had long been required and he congratulated the Author on his solid contribution to such a history. It should be remarked that Smeaton followed in his boring mill the earlier gun-boring machines. With regard to the vertical boring mill, he might mention one peculiarity that was not found in horizontal machines and that was that they used to make a back thread in the cylinder. It was probably to avoid this that Boulton adhered to staggered cutters.

MR. H. W. DICKINSON remarked that from his study of Wilkinson[10] he

[7] *Trans. Inst. Mech. Eng.*, 1903, p. 673.
[8] *Experimental Philosophy*, p. 536.
[9] Boulton & Watt Colln., Birmingham.
[10] John Wilkinson, Ironmaster, 1914.

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would judge, and the President agreed with him, that Wilkinson was not an orginal inventor but that he was every ready to take up a good idea. It was quite likely that the gun-boring machine which he patented was not his own invention but that he had imported it from abroad. Certainly such appeared to be the case in his method of making lead pipe which he patented in 1790 for it was fully described[11] in a French publication more than sixty years previously. It would be admitted that Wilkinson was the first to introduce into this country the bar for boring.

MR. A. G. SCHOLES and MR. T. CLARKSON also took part in the discussion.

MR. E. A. FORWARD, replying to the discussion, considered it quite probable that Wilkinson had seen a machine, like the mill mentioned by Mr. Hulme, somewhere abroad. There was one actually described in a Swedish publication[12] in 1782. The same thing might hold good for the cylinder boring machine, and his experience with the patent for the former may have deterred him from taking out a patent for the latter. The Author was glad to have the information that Ewart's mill was not actually constructed. The letter from James Watt, dated 1802, was important, as it shows, in the absence of evidence of earlier use, that the automatic screw feed was due to Matthew Murray. Mr. Tyas had mentioned several later machines, but the paper only dealt with those made prior to 1840, by which date the form had become established.

[11] Machines approuvées par l'Académie des Sciences, Vol. V., 1728, p. 53.
[12] Kongl. Vetenskaps Academiens nya Handlingar III., 1782, p. 276 & Tab. IX.

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Some Windmills of Cape Cod.

BY

Edward Pierce Hamilton.

(*Read at Prince Henry's Room, Fleet Street, Jan. 28th, 1925, and at the Engineers' Club, New York, April 22, 1925.*)

In the early days of the settlement of New England there were many windmills in use, particularly on the shores of Massachusetts Bay. The first of these is probably that which stood at Watertown, near Boston, previous to 1632, in which year it was moved on to Boston Neck in order to secure better wind conditions. In Somerville there still stands the stone tower of a windmill built in 1704. It did not long continue in use as a mill, for it was sold to the Province in 1747 for the storage of powder. This old mill was the powder house of the Colonial troops during the siege of Boston in 1775-76. There were many other windmills in the vicinity of Boston and along the shores of the Bay. To-day they are all gone, and, with one or two exceptions, the only remaining examples are those found on Cape Cod.

Cape Cod is that long peninsula of sandy soil, which, curving out into the Atlantic like an arm, encloses Massachusetts Bay from the open ocean. The most interesting of the mills remaining there are those at South Yarmouth and Chatham (see Plate IX.), and it is these two, largely, that will be described. They are much the same in outward appearance, and a close similarity in construction renders it probable that they were built by the same man. Both bear the date 1797, and there seems no reason to doubt but that this is correct. Inside and out they are very little changed from the condition in which they left the builder's hands.

They are tower mills, octagonal in shape, and about thirty feet in height to the top of the cap. The sails are just over fifty feet from tip to tip. The cloth sail covers were tied in place on the frames when the mill was to be run, and iron eye bolts at each of the corners of the tower allow the sails to be chained fast when the mill was not in operation. The revolving cap is rotated by means of a long wooden tailbeam, to the lower end of which a wagon wheel is attached. All of these Cape Cod windmills are worn and weatherbeaten, and, occurring as they do in a region of low hills and sand dunes, they make a most attractive addition to the landscape.

These mills are built largely of oak. Eight timbers are erected upon the foundations and pinned at their upper ends to the circular wooden ring upon which

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the cap rotates. Horizontal cross timbers tie these together at intervals of about eight feet, and diagonal braces are framed into the resulting quadrangles. The whole frame, except for the doors and windows, is planked over, and then covered with shingles. The revolving cap rests directly upon the top of the structure, without rollers, but a liberal use was made of grease.

Most of these mills have three floors. The lowest, elevated slightly above the ground, contains the corn cracker. This machine, almost always met with in New England mills, stripped the Indian corn (maize) from the cobs upon which it grows. The corn was then carried to the second floor, where the millstones are placed. The top floor furnishes access to the gearing and the bearings.

The wind shaft found in most of the remaining mills is of pine. A wrought iron gudgeon is fastened to the rear end by iron hoops and hardwood wedges. The forward bearing is the full diameter of the shaft (about 18in.), which is protected against wear at this point by means of iron strips let into the wood flush with the surface (Plate X.). Instead of being fastened with hoops, as described by Mr. Titley in his "Notes on Windmills,"[1] every strip is spiked to the shaft at each of its ends. The old millwrights called these strips "whelps." This type of main bearing is found in almost all the wooden shafted mills on Cape Cod. The shaft rests upon a cast iron pillow block in the South Yarmouth mill. The bearings could not be examined in the Chatham mill, but the miller who last ran the mill said that it was of stone.

The brake wheel in both of these windmills is eight feet in diameter, and carries forty-eight cogs. It is built up of two or three layers of "cants" to a thickness of eight inches. Four arms attach it to the windshaft. The outside is surrounded by a brake, consisting of a number of curved wooden sections hinged together at their ends.

The vertical shaft is about 8in. diam. An iron gudgeon in its upper end runs in a wooden bearing on a cross-piece below the windshaft. At its lower end, just above the mill-stones, the spindle, an iron bar 2½in. square, is fastened with loops and wedges. This spindle goes through the wooden "bush" in the nether stone and then to the lower floor, where it drives the corn cracker. In the Chatham mill the pinion of the vertical shaft is made of cast iron; at South Yarmouth it is a wooden trundle gear with cast iron rungs (Plate X.).

While most of the Cape Cod mills appear to have been tower mills, there were some post mills. The one remaining example is near South Brewster. The post is much shortened, and the mill is partly, if not wholly, carried on iron rollers moving on a wooden track. The windshaft has a cast iron front, and is the only example of such construction found in the mills visited. This mill is certainly of a later date than any of the others. All the other mills show a great economy

[1] *Transactions*, III, 64.

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in the use of iron. The main bearing, the gudgeons, the spindle, the pinion gear, and the minor fittings are iron, but practically everything else is of wood. Wooden pins and treenails are used almost entirely.

The Eastham mill, which is probably well over a hundred years old, has been partly rebuilt. The cap is carried on rollers, and is much newer than the rest of the structure. Instead of having a slanting timber for turning the cap, a horizontal spar is used. This carries a counterweight suspended from it by a rope, thus helping to balance the weight of the sail arms and allowing the cap to be rotated from the ground. This mill represents the Cape Cod windmill in its most improved form; the new cap and its mechanism date from perhaps 1870.

These Cape Cod mills represent the highest development of the windmill in New England, yet it is evident that they are crude and primitive and show little advance over the windmill as it existed in England at the time of the Puritan exodus (1620-40). In fact, these mills probably are close counterparts of the English windmill of the first half of the seventeenth century. A large portion of the immigration to New England came from the Eastern Counties.[2] Commencing in about 1620, the period of migration to Massachusetts Bay came to an abrupt end at the start of the Civil War, and, with a very few exceptions, there was practically no addition to the population of New England until after the Revolutionary War. It seems reasonable to suppose that the windmills of these early settlers should be modelled after those they knew at home.

The Pilgrim settlers of Plymouth had been under Dutch influence during their years at Leyden, but they endeavoured to retain their English life and customs. Indeed, the fear of being assimilated by the Dutch was largely the cause of their emigrating to a new country. No signs of Dutch influence ever appeared in New England. In view of this, it seems reasonable to state that the windmills from which these Cape Cod mills developed were English windmills of the period 1620-40, and, moreover, that they probably reflected the practice of the Eastern Counties.

New England windmills never reached a stage of development much beyond that of these early mills. They contained only the bare essentials. None probably had more than a single run of stone, and none of the later improvements, such as the " lift-tenter " and " fantail " gear, were used. The reason for this lack of development is easily explained. New England is a land of most abundant water power. Almost all the early settlements had streams near at hand, and water mills were soon built. It was only in regions such as Cape Cod, where there are few water powers, that windmills continued in use beyond the early days. This restricted use of windmills meant that there was a lack of incentive toward their improvement, and that the later mills probably were copied

[2] John Fiske, *The Beginnings of New England.* Boston, 1898.

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from their predecessors with little, if any, change. In fact, it is almost safe to state that these mills, particularly the one at South Yarmouth, are in all their essentials almost exactly the same as the English tower mills of the seventeenth century.

The Chatham mill was running as late as 1916, but corn has not been ground regularly for many years. The mill needs only a few minor repairs to put it in running order. This also applies to South Yarmouth mill. The Brockton mill was unfortunately burnt down in 1924. Most of the other windmills have either been put to other uses or allowed to fall to decay. The old millwrights built solidly and well, but time is gradually doing its work, and, with one or two exceptions, no attempts are being made to keep the windmills in repair.

In the early days every New England town had its grist mill, where its corn was ground. Indian corn was then the common food of the people. English wheat had been cultivated during the early years of settlement, but it did not flourish, and soon ceased to be sown.[3] The advent of the railroad changed all this, and our wheat now comes from the West already milled. Hence the grist mill has almost entirely disappeared. Here and there you may occasionally find one running a little, usually cracking corn for cattle feed, but the little mill, once indispensable, is now a thing of the past. The displacement of the little local mills is only another result of the centralizing and specializing trend of the present day. Before many years have passed the few surviving grist mills will have tumbled into ruins, and they, too, will become but a memory. The New England of to-day is far different from what it was half a century ago. New races and new customs have been added, and the final result is yet to be seen, but old-time New England is gone for ever.

We are fortunate that these few remaining windmills have lasted down to our day, and that we are able, from studying them, to realize and appreciate the great skill and painstaking care of their builders, the millwrights of old.

The paper was illustrated by ten photographs, from which a selection for the Illustrations (Plates IX. and X) has been made.

The paper was read for the Author by MR. A. TITLEY, who opened the

DISCUSSION.

He said that the mill-work generally corresponded with that found in England in the middle of the 18th century, before the introduction of cast iron parts which, principally due to John Smeaton, came into use about that time. The absence of graduated weathering to the sail-bars and their equal extension on

[3] Wm. B. Weeden. *Economic and Social History of New England.* Boston, 1890.

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either side of the whips, and the existence of wooden shafts with wrought iron strips to form the bearing surface of the journal, point to the very early introduction of mill-work to America which was not followed by the adoption of later Dutch and English developments. The survival of such archaic examples in the United States is most interesting. Perhaps Dutch influence may be seen in the construction of the octagonal timber towers which were a feature in the millwright's practice in that country, and an examination of details of construction of these towers might be worth while.

MR. E. LANCASTER BURNE drew the Author's attention to an interesting paper entitled "Some Ancient Windmills on Cape Cod," contributed to "The American Machinist" by Snowden B. Redfield, he believed in about the year 1909. Several mills in the neighbourhood of Cataumet (Mass.), East Orleans, West Falmouth, and Hyannisport are described and illustrated. The towers of these mills are octagonal and square in shape, and are generally surmounted by a high peaked cap—the whole design being rather suggestive of the tower mills still to be found in France, and also bearing a resemblance to an old mill that exists, or did exist, near Leamington. In most cases the whip lies in the centre of the cross bars of the sweep, the bars being weathered to a uniform angle; but in one or two instances the sweeps are more or less of the present-day type, with a varying twist and a leading board.

He (Mr. Burne) hazarded the opinion that the former and cruder type of sail might be a replacement effected for appearance sake by someone without millwrighting knowledge, seeing that the ages of the mills mentioned were generally assumed to be about 160 years. There is no doubt that the Dutch type of cloth sail, which survives to this day, is considerably older than this. He knew a mill in this country where dummy sweeps, weathered *in the wrong direction*, had been fitted!

It was a fortunate circumstance that interest was being taken in these old American windmills, and that some of them, at any rate, were being cared for. One, for instance—at West Yarmouth—appears to have been moved to its present site for preservation some 30 years ago, and to be in sufficiently good repair as to render it still capable of grinding corn.

MR. MURRAY KENDALL could not throw any light on the mechanical side of windmills, but in connection with the Ancient Monuments Commission he had made some study of their architecture. He had examined a windmill at Brill, in Bucks; the date, now partly defaced, was early in the 17th century. This had a sloping roof. Older mills had ogee tops, *i.e.* with a double curve.

MR. TITLEY, in reply, said that one proof of Dutch influence was the wooden construction of the tower. One old American mill with such a tower was burnt down just as it was about to be moved.

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It was difficult to say when cast iron was first used in windmills. In the early days a tree bored to receive an iron spike constituted a wind shaft. The ogee top originated in Holland, and Smeaton used it, but few examples exist outside Lincolnshire.

As to the mill at Brill, there is a good deal of speculation as to whether it is a windmill or not, as its site is unsuitable.

A hearty vote of thanks to the Author was passed by acclamation.

MEETING AT NEW YORK.

MR. EDWARD P. HAMILTON was present, and gave the paper in abstract. He submitted his collection of photographs of mills built by the early settlers in Massachusetts and Rhode Island.

In reply to discussion, he mentioned that the stone tower at Newport, which had been assumed[4] to be a relic of the Norsemen, was in reality the base of a windmill.

[4] c.f. Longfellow, *The Skeleton in Armour.* 1842.

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Notes on a Neglected Worthy, John Patison of Airdrie.

BY

David Brownlie, B.Sc. (Hons.) Lond., F.C.S., etc.

(*Read at Prince Henry's Room, Fleet Street, Jan. 28th,* 1925.)

In the writer's opinion, one of the most useful functions of the Newcomen Society is to trace out and put on record the work of the many, who may be termed lesser pioneers in engineering and technology whose names are now almost forgotten, in spite of the important and meritorious part they have played.

A good example is John Patison, of Airdrie, one of the numerous original and to-day unrecognised workers who helped to build up the carbonisation industries. The writer has been devoting for a number of years past some considerable attention to this field, more especially from the point of view of what is termed low temperature carbonisation, and in the course of this work he has been fortunate in being able to get together quite a large amount of information concerning Patison, whose main achievements are the production of what is apparently the first practical internal screw conveyor horizontal carbonisation retort, and his work in the evolution of the shale oil industry.

In this connection, the writer wishes to express his sincere thanks for the assistance given to him by Mr. Archibald Kellock, Engineer and Manager of the Burgh of Airdrie Gas Works, and the Hon. Sheriff James Knox, of Airdrie, along with Mr. John W. Patison, of Montreal, and Mrs. Thomas Taylor, of Edinburgh, John Patison's son and eldest daughter respectively, whilst he has to thank Mrs. Taylor also for a daguerreotype of her father, reproduced herewith. (See Plate XI.)

John James Patison, to give him his full name, was born in Leith in April, 1828, his father being an Edinburgh man. When a boy, he was first employed at a bookseller's shop in Edinburgh, and then served his time with the Commercial Bank in the same city. He subsequently left the bank and started a salt works at Musselburgh, near Edinburgh, which business he sold in 1854, finally removing to Airdrie. Here he lived at a house called Barblues Cottage, and, like William Murdock many years previously, commenced experiments, in the garden, on the carbonisation of shale, obtained from an adjoining deposit. Mrs. Taylor informs the writer that she remembers his first experiments were carried out by grinding the shale, putting it in the bowl of a common clay pipe, covering the charge with

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wet clay, and then heating the bowl in a fire, collecting the oil that came off from the end of the stem.

Following upon these early experiments, he started shortly afterwards a chemical works at Stand, near Airdrie, which was subsequently removed—either in 1856 or 1857—to Whiterigg, also near Airdrie, and was known as the Whiterigg Chemical Works.

The first process carried out was the distillation of shale refuse for the production of oil, and Patison was certainly one of the earliest practical workers in the commercial development of the Scotch shale oil industry. It is known that shale, torbanite, cannel, and similar material has, like coal, been carbonised from the earliest times. Thus one of the first British patents, that of Martin Eele, Thomas Hancock, and William Portlock, No. 330, A.D. 1694, is for the manufacture of "pitch, tarr, and oyle out of a sort of stone," obviously refers to shale, and in 1781 Lord Dundonald carbonised shale in his search for a substitute for Stockholm tar.

One of the practical pioneers of modern shale carbonisation, and certainly the founder of the Scottish shale carbonisation industries, was James Young, who had been the manager of a chemical works in Liverpool, and who built in 1848, at Alfreton, in Derbyshire, on the advice of Dr. Lyon Playfair, a small plant to refine a natural seepage of oil in the locality. This supply was exhausted in two years, and Young then investigated in the laboratory all kinds of natural carbonaceous materials, with a view to finding a fresh source of oil. He finally selected a variety of torbanite found at Bathgate, in Linlithgowshire, the so-called "Torbanhill mineral," as the most suitable, and he took out in 1850 his famous British patent No. 13,292, thus inaugurating the shale oil industry in Scotland.

In partnership with Meldrum and Binney, Young set up his first works at Bathgate that same year, and continued to use torbanite until 1862, when the supply failed. As a result, the much inferior shale had to be employed instead, and it has generally been understood that the first to do this on a large scale was Robert Bell, at the Broxburn Oil Works, in 1862. If, however, Patison carbonised true shale, say, somewhere about 1855 or 1856, at Stand or Whiterigg, of which there seems to be no doubt, he was long before Robert Bell, although, as already indicated, James Young must have experimented in the laboratory with shale about 1850.

When James Young first started his works at Bathgate, he used simply the ordinary horizontal gas retort, mostly in vogue at that time, that is a horizontal, externally fired, ⊓-shaped, intermittent, cast iron retort. This, however, was unsatisfactory, and Young experimented with all kinds of retorts, finally adopting in 1860 a vertical, externally heated, intermittent, tapering, cast iron retort, although he continued his investigations, and one of his best-known vertical retort patents is that in 1867 in conjunction with Peter Brash. Incidentally, this type

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of retort, from which has been evolved the modern vertical gas retort, was the original invention of John Brunton, in 1828, and used by him for the carbonisation of coal on a very large scale at West Bromwich gas works.[1] As is well known, the Scotch shale industry has since remained faithful to the vertical retort, commencing with the Young and Price designs of 1860, right down to the modern Henderson, W. Young and Beilby, and Pumpherston retorts.

Patison also first used at Whiterigg for shale carbonisation in 1856 the ordinary cast iron Ω -shaped horizontal externally fired, intermittent type of gas retort, and Mr. John W. Patison states that he remembers twelve of these retorts being cast in Airdrie, whilst the steam boiler, engine, compressed air pumps, condensers, and other apparatus for the new works were mostly supplied locally. The shale was obtained at a price of 6d. per ton, apparently from the refuse banks of the Calderbank coal pits, having accumulated in the screening of the coal, and the crude oil obtained was sold in Stirling at 3s. 9d. per gallon. The business was very successful for a number of years, until the crash of the Scottish shale oil industry due to the discovery of American petroleum, and the distillation of shale at Whiterigg was eventually closed down about 1864.

Patison's first British patent for the internal screw conveyor retort was No. 757, A.D. 1870, being of horizontal cast iron construction, externally heated, with a cast iron screw conveyor, specially intended for the carbonisation of spent dyewood residues and the manufacture of charcoal. One of the subsequent products of the Whiterigg Chemical Works was acetic acid and other substances from the carbonisation of wood, including charcoal.

It would take up too much time to discuss the details of this first retort, but the design was of an extremely efficient and well-thought-out character for the purpose, and presumably Patison used it at Whiterigg in connection with the manufacture of acetic acid. Incidentally, it is not known when he first commenced to carbonise wood on a commercial scale, but apparently it was before 1870, and presumably he must have used at the beginning the ordinary simple intermittent type of closed retort such as then in vogue, subsequently inventing the much improved and more complicated internal screw continuous installation.

It is his second Patent, No. 569, A.D. 1873, that interests us more particularly, because it was an internal screw, externally-heated, mechanically continuous retort intended for the carbonisation not only of wood and other similar material, but also coal and shale, or mixtures of these (*see* Plate XII.).

Very many attempts have been made to use for the carbonisation of shale and coal, especially in the latter case by low temperature methods, retorts on the internal screw continuous principle, either with internal or external heating, and of the vertical, inclined or horizontal variety. Prominent among the low tem-

[1] *Transactions*, III, 64.

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perature carbonisation methods on this principle are, or have been, the " Del Monte " process, the so-called " Chiswick " retort, the " Burney " retort patented by Commander C. D. Burney of paravane fame, the F. W. Marshall and E. W. Easton patents, and the " Greene-Laucks " and the well-known " Smith-Carbocoal " processes in the United States, as well as a number of shale processes in Colorado and Utah for the rich Western American shales.

The archimedean screw is one of the earliest of all mechanical inventions, but so far as the writer can trace, its first application to the process of carbonisation, forming an integral part of a retort and operating in the heated charge itself, is that by the Count de Hompesch, apparently an Austrian, in 1845, although, like several American inventors before 1865, he seems to have used it to agitate the charge only and not to convey it at the same time. It should be emphasised that screw conveyors were used before this time for feeding coal into retorts, but they were not actually operating at high temperatures. One of the first known applications of this principle is that of George Bower in 1857, whose retort design is obviously, however, copied from the earlier work of John Brunton between 1825 and 1840, who used a piston instead of a screw feed for feeding the coal.

The first definite use of the internal screw conveyor carbonisation retort appears to be that of Wilhelm Ziervogel of Prussia, whose very remarkable British patent was taken out in 1858, for use mainly in connection with Saxon brown coal carbonisation industry, although intended also for shale. This was a vertical retort of a very efficient design, but from the screw conveyor point of view only the screw had a very shallow thread and was intended more to assist the action of gravity, the charge travelling downwards.. This invention is, however, in general of such an advanced character, with a hollow perforated large diameter screw shaft, for example, to act as the discharge for the gaseous and volatile products evolved, that it is almost presumptive evidence the screw conveyor retort in one form or another was used by other unknown workers before 1858, as one man could hardly have produced such a complete design without previous knowledge to go upon.

Further, James Dougan in 1865 seems to have been the first to use a horizontal screw conveyor retort with a hollow shaft through which heated gaseous products were passed so as to give some measure of internal carbonisation, whilst in 1866 James Young devised a horizontal continuous externally fired retort for shale which acted on the same principle as a screw conveyor retort, except that the horizontal cylinder revolved bodily and there was fixed inside a special steel blade or projection in a spiral form, giving the same effect.

Patison's internal screw conveyor retort of 1873 (*see* Plate XII.) is also of advanced mechanical design, and in many ways practically on modern lines. The retort was made slightly sloping and was constructed of cast iron in two lengths

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bolted together, having removable ends screwed or arranged in such a manner so as to make a tight joint, the over-all dimensions being 18 to 30 feet in length and 8 in. to 16 in. internal diameter, whilst the section was circular, although an oval shape was also mentioned. Further also the retort tapered slightly towards the discharge end to allow for the expansion of the charge, and was built in a brickwork setting on the usual lines, the external heating being obtained by the furnace at the bottom discharge end, which itself was also supplied with fuel by means of a screw conveyor. The retort conveyor is of excellent design, built up of a large diameter hollow cast iron shaft, provided on the outside with a cast iron continuous hollow projecting thread forming the screw conveyor, and the shaft was also fitted with an arrangement so that a small but continuous current of cold water could flow through it, thus reducing the wear and tear due to the great heat of the charge. This principle of a large diameter hollow shaft to carry the screw as used previously by Ziervogel, is of course a very great improvement for a horizontal retort on the small solid shaft which is easily bent and the supporting journals at each end were also of excellent construction, with gas-tight stuffing boxes packed with asbestos.

The drive was at the top end by means of worm and gear wheels, whilst the fuel was fed in continuously from a charging bell or hopper and conveyed through the retort by the screw as it was carbonised, the heating also being progressive in the sense that the flames and hot gases entered the setting at the discharge end and passed the reverse way to the chimney. The gaseous and volatile products evolved by the carbonisation were given off through the two connected discharge pipes at the top, passing through a condensing plant of the ordinary character.

One of the chief difficulties with the internal screw conveyor retort for plastic and swelling material, such as bituminous coal and to a lesser extent many varieties of shale, has always been the jamming of the screw by the charge, and this was subsequently obviated by various devices, such as for instance a double screw with intermeshing threads. Patison appears to have been the first man to devise an apparatus for this purpose, which consists in principle of a single or double thin scraper, of steel or iron blades, fitted at one end of the retort, clear of the extreme end of the screw blades or projecting thread. This scraper is attached to a long parallel rod or handle operated through a stuffing box in the end cover of the lower part of the retort, and when cleaning is required the rod is pushed forward into the retort the necessary distance and the screw conveyor made to revolve in the reverse direction. Consequently the scraper becomes intermeshed with the thread of the screw and is caused to travel downwards, cleaning the screw as it goes along. The screw conveyor is then reversed in motion and the scraper returns to its original position. Whether this principle was a success with shale is not stated, but it was certainly inadequate for bituminous coal, and incidentally

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it may be stated that up to the present day no internal screw conveyor retort has yet been a commercial success, because of the many practical difficulties in the way, unless it be the new McIntire retort at Fairmont, W. Virginia, U.S.

It is clear also that Patison intended to use this retort either for low temperature carbonisation, so as to give the maximum yield of liquid products, or at a much higher temperature if illuminating gas was to be the chief requirement with the liquid products of little importance. If this is the case as applied to coal, Patison was also one of the earliest workers in low temperature carbonisation, but the facts are not clear, although there seems to be no doubt that many investigators from the very earliest times were well aware of the difference in the quality of the tar obtained according to the temperature of carbonisation.

Mr. John W. Patison states that this internal screw conveyor was not erected at Whiterigg, but in another works by a Mr. Simpson of Benhar, to whom Patison had sold the rights of large seams of shale he had discovered on the Bennend Estate in Fifeshire, and also near Burntisland. Twelve of these Patison internal screw conveyor retorts were set in operation for shale, and Mr. John W. Patison saw the installation at work. It seems to have continued in use for a number of years, showing a great saving in labour, but the chief trouble was the wear and tear and cost of maintenance, which still holds good to-day for screw conveyor retorts. Ultimately the whole installation was abandoned and replaced by the Henderson vertical retort then just set in operation at Broxburn.

Another subject in which Patison interested himself was the distillation of tars mixed with common salt or potassium chloride, and certainly from his private papers—which the writer has been allowed to go through—he seems to have carried out a large amount of experimental work in this direction..

The idea of using various salts in connection with crude tar so as to improve the quality of the oils fractionated seems to have attracted many investigators about this time, and for example James Young, in a provisional specification, A.D. 1868, No. 1868, claims the principle of heating or distilling paraffin wax, paraffin oil and petroleum in contact with alkalis or alkaline earths. Patison states in his memoranda that as a result of his experiments he is convinced that not only does salt added to tar improve the products, but that potassium chloride gives much better results than common salt itself, the yield on fractionation, as he expresses it himself, giving " different and superior oils." At first there would seem to be nothing in this idea, and it was abandoned a long time ago, but with our modern chemical knowledge—especially in the last few years—in connection with catalysis, for example, one hesitates to disbelieve almost any statement without actual experimental evidence, especially in the case of such a complex mixture as tar from the carbonisation of coal and other carbonaceous material.

This idea of the useful properties of salt is prevalent throughout the world,

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and an amusing example is that many people even to-day imagine that the evolution of black smoke from bituminous coal in the open household fire can be prevented by sprinkling salt upon it, whilst it was not very long ago that a well-known firm of mechanical stoker makers in Great Britain took out a British patent for the use of salt water in making steam for the nozzles used under the moving firebars, as they contended that the minute trace of salt in steam made from salt water in this way improved the efficiency of combustion in the fires, although according to their own statement the amount of steam consumed by the nozzles was only a mere fraction of the production of the plant.

Many other examples of the use of salt can be found scattered throughout literature, and for example Dr. Ludwig Mond, in his well-known investigations which resulted in the production of the " Mond " gas process, also tried the effect of moistening coal with salt so as to try and improve the ammonia yield. Patison may therefore certainly be regarded also as one of the earliest workers on this idea of the benefits—mythical or otherwise—to be obtained by the use of salt in many chemical reactions.

All his life, Patison remained keenly interested in the shale oil industry and his private papers show records of many experimental borings that he made in many different parts of Scotland, whilst, further, he was associated with some iron ore mines in the Tyrol. He carried on the Whiterigg Chemical Works along with his son until 1886, when he retired from active business, and died at Inverkeithing, Fifeshire, in July, 1905.

I think it will be as well to conclude this short contribution by giving the following extract from a private letter concerning John Patison that was written this last year by a gentleman who was well acquainted with him personally:—

> " He was a great friend of my late father, by whom he was regarded as an extraordinary man in many respects. Not only was he a chemist of more than local repute, but a man of the very highest scholastic attainments, and a cultured and courteous gentleman. He was very reserved in his habits and reticent to a degree with those who did not know him. . . . He was consulted on technical matters by many ' big pots ' in the oil industry, and he invented and perfected many contrivances which he disposed of for the proverbial old song and enriched others."

Other people who knew him well were also of the opinion that, like many inventors, he thought little of the financial side of his work, and his life is certainly an example of the debt we owe to many early and almost unknown pioneers in every walk of technical life.

The paper was illustrated by a portrait of Patison and by copies of his patent specifications; from these plates XI. and XII. have been prepared.

A vote of thanks to the Author was carried on the motion of the President.

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DISCUSSION.

MR. DENDY MARSHALL thought the use of salt in tar distillation to improve the quality of the oil, very curious.

MR. A. SCHOLES said it was a common practice in India and China to add salt to paraffin oil. He had tried it and it improved the lighting effect.

MR. E. WYNDHAM HULME stated that Betton's patent of 1742 [No. 587] was revoked by the Privy Council on the ground of want of novelty, Eele's patent of 1694 [No. 330] being cited as an anticipation; presumably therefore coal distillation had been done previously.

THE PRESIDENT said he did not know whether Eele used shale; it was recorded that he used the sandstone found over the coal at Broseley, near Coalbrookdale.

MR. NORMAN SWINDIN reminded the meeting that the use of salt on coal was advocated during the war as a measure of economy. He thought there was a good deal of confusion in early accounts between vegetable tar and coal tar. The Earl of Dundonald invented a process for distilling tar from coal in 1780. A notice, dated 1785, stated that " trials for getting tar from coal had been made by the Earl of Rockingham at Coalbrookdale." The coal gas escaped into the air as a waste product. The tar could not be sold at a profit as the expenses were so great, and Dundonald succeeded in losing his money.

THE PRESIDENT said that at that time people were quite alive to the fact that coal gas would give light and they had the idea of distributing it, but there were no means of doing so for iron pipes did not exist.

MR. BROWNLIE mentioned the use of old muskets as pipes in the early days of coal gas hence the term " gas barrel."

MR. J. MACFARLAN said the town of Whitehaven in 1765 opposed a plan for supplying the town with gas from a colliery near by.

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George Dixon : Discoverer of Gas Light from Coal.

BY

J. Macfarlan, Member.

(*Read at Prince Henry's Room, Fleet Street, Jan. 28th, 1925.*)

For over a hundred years William Murdock has generally been regarded as first inventor and practical founder of the industry of gas making in England. No doubt worth notice disturbed that belief until June, 1924, when Mr. Waynman Dixon, J.P., Great Ayton, Yorkshire, in a letter to *The Times*, claimed the invention for his great-great-grandfather, George Dixon, of Cockfield, County Durham, whose experiments were made so long ago as *circa* 1760. Modest and retiring, Dixon did not advertise in his day, and since his death his descendants have omitted until now to secure his right. The writer has investigated this claim, and has gleaned a few scraps of information about Dixon that are here set forth.

George Dixon was a colliery owner, and interested in various mine adventures. One of the earliest projectors of canals in the North, he also introduced several ingenious modes of transporting coal from the pits to the Tyne. Almost anything in discovery or invention might be expected from the subject of such a eulogy as the following:—" George Dixon was a very ingenious man,—a mathematician, a mineralogist, a painter, an engraver, a great experimentalist in chemistry, hydraulics, and pneumatics; also an excellent land surveyor, and ' a most beautiful planner '."[1]

For the little that we know of Dixon's experiments we are indebted to his nephew, John Bailey, who was tutor to his sons, and later became agent to Lord Tankerville. His book[2], due 1796 but delayed for fourteen years, was fifty years later than the events it describes; by 1810 gas lighting was spreading rapidly, and Murdock was hailed as its *fons et origo*. Bailey's statement is that before or about 1759 his uncle had discovered the process of extracting tar from coal. This discovery induced him to experiment with coal gas, which then led to his experiments to obtain a new and greater illuminant than any in use. One of his domestic " tests " is described by Bailey as follows:—

" I remember being much amused when a little boy by his filling an old tea kettle half full of coals, and setting it in the fire, and luting a tobacco pipe with clay

[1] Mackenzie and Ross : Historical View of... Durham, 1834, II., 312.
[2] General View of the Agriculture of Durham, 1810, pp. 290-2.

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to the spout, and to this several others round the end and side of a room: after a certain time he put the flame of a candle to the end of the farthest pipe, and immediately a bright flame issued from it, where nothing was perceptible before: he made small holes with a pin through the clay that luted the pipe heads and shanks together, and applying the flame of a candle to each, there were as many flames as pipe heads. He had only made the discovery a little before, and this was probably the third or fourth exhibition of illuminating rooms by gas lights. This mode of lighting rooms was for a long time a favourite project with him, and he had thoughts of lighting his collieries with them, but was cured by the following experiment, at which I was present:—

"Wanting to know the quantity of tar produced from a ton of coals, he erected a furnace, with a large cast metal boiler, in which coals were put; to this were fixed two large metal pipes; one of them passed through water, in order to condense the oil and tar; the end of this was filled by a wooden plug with a small hole to let out the tar, etc. Towards the close of the experiment, he placed the flame of a candle to this hole; the inflammable gas immediately burned with a large, bright flame; to extinguish this he struck at it with his hat: the flame was driven inwards, the gas in the inside of the apparatus took fire as quickly as gunpowder, and exploded with a report like a cannon, driving out the wooden plug to a great distance, and exhibiting a cylindrical body of fire several yards in length; the heavy cast metal pipes were removed from their places. From this time he considered his project of lighting collieries and rooms with gas lights as very dangerous."

The three or four experiments cited seem to have been the first attempts on record to obtain light from coal in a scientific manner. From that elementary production of his new light, Dixon is supposed to have progressed to the later and more elaborate combination of means for obtaining coal gas that is depicted on the accompanying sketch, which is entitled "Preparation of Inflamable Gas by George Dixon." (See Plate XIII.)

LEGEND.[3]

A. Iron cylinder or retort half filled with coal (a fire should have been shown under it).

B. Drain for coal tar, etc.

C. Barrel used as gasholder, (the upright pipe with cock on the left is evidently an escape pipe).

D. Cock for turning on the gas.

E. Flare of gas lighted.

The words "About 1760" were added recently by Mr. Waynman Dixon.

The sketch speaks for itself; but when he evolved the "plant" it shews is

[3] Supplied by Mr. W. Dixon. There is no legend attached to the drawing.

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unknown. If Bailey knew of it, or had seen it in operation—and both are probable—he, unfortunately, is silent on this most important point. Dixon's descendants, however, believe this sketch to be his own original drawing of his apparatus for lighting rooms and collieries.

Seeing that in Dixon's day there was practically no scientific data or previous research to guide him, his conception of the means necessary for the end in view is remarkable, and may be called an inspiration. We gain some idea of his originality by comparing the parts of his apparatus shown on the sketch with that used by Murdock at Neath Abbey Iron Works in 1796[4], which was merely "an iron retort with an iron pipe three to four feet in length, at the end of which the gas was burned."

Murdock came on the scene when England was beginning to hum with great inventions; when numerous experimenters, here and on the Continent, were studying the "spirit of coal," hydrogen, etc., in vain searches for a new Aladdin's lamp. Masse[5] sums up their work as mere "tours de physique amusants" with two exceptions: One was that of M. Minckelers, Professor of Physics at Louvain, who, after many years' experimenting with coal gas, lighted his class rooms with it in 1787; the other was that of Lord Dundonald in the same year, when he used gas lights in his hall at Culross Abbey. The idea had been suggested by an explosion in his tar kilns; so his distinction was to begin where Dixon had left off.

In his Paper to the Royal Society,[6] Murdock admits he knew of Dr. Clayton's bladders inflated with gas for burning, and of the frequent firing of Dundonald's tar ovens, but concludes: "I claim both the first idea of applying, and the first application of this gas to economical purposes." The latter half is not in question, nor is his work in devising plant and in purifying the gas. But his claim to the "first idea of applying" coal gas for lighting can hardly be maintained against the priority of Dixon and Dundonald in England, not to mention Minckelers abroad.

A vote of thanks to the Author was carried by acclamation.

DISCUSSION.

MR. E. W. HULME pointed out that the sketch in its original state was neither dated nor signed. The handwriting was not like that of the middle of the 18th century. He would put it at least half a century later.

MR. NORMAN SWINDIN confessed he had first heard of Dixon's claim in the letter in *The Times* alluded to. The Dutch claimed that Minckelers was the first inventor.

MR. MACFARLAN, in reply, said there was still a wide field in which to search for possible references to Dixon's discovery, and the points referred to must stand over till such search had been made.

[4] Dict. Nat. Biog. *Art.* Murdock.
[5] Masse, René, in his comprehensive work *Le Gaz*, 1914, I., 19-27.
[6] *Phil. Trans.*, 1808, 124-132.

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Loan Exhibits.

(*Shown at Prince Henry's Room, Fleet Street, January 28th*, 1925.)

The exhibits, of which a list is appended, were shown at the meeting on the above date, and excited considerable interest, but the time available for their proper inspection was hardly sufficient.

Shown by C. F. Dendy Marshall, M.A.

Battersea enamel patchbox—View of Coalbrookdale Bridge, 1779.

Earthenware plaque—View of Sunderland Bridge, 1796.

Thomason's Scientific and Philosophical Medals, 1829.

British Railway Medals (21), down to 1842.

British Railway Medals (24), 1842 to 1909.

General Engineering Medals (38).

Autograph letter—Robert Stephenson to George Stephenson, April, 1829.

Engraving of locomotive No. 28, Liverpool and Manchester Railway.

Shown by H.M. Patent Office, *per* A. A. Gomme, A.C.G.I.

Copy of Johann Cuba's botanical work *Ortus Sanitatis*, Augsburg, 1485, with cuts in text coloured by hand.

A.L., Dr. Samuel Johnson to Lewis Paul, with respect to a proposal to borrow money on the security of Paul's spinning machinery, 12th March, 1756.

Facsimile of German MS. relating to a flying machine, 1784.

Shown by the Director, The Science Museum, *per* the Hon. Sec.

Objects from James Watt's Workshop, recently removed from Heathfield, viz., pocket lens; engineers' square with Watt's name on it; folding wedges; engine counter; revolution counter; model of Watt's semi-rotary engine; and an unidentified object.

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Gun-making Handicrafts.

BY

C. E. Greener

(Read at Prince Henry's Room, Fleet Street, London, March 4th, 1925.)

Early cannon, from which the gun was ultimately derived, were cumbrous, and generally ineffective weapons of the mortar type. The smaller cannon were forged of iron strips and hoops, built up as a tub is made, one end blocked with a piece welded in, or stoppered by a movable plug wedged up against the breech-end.

Cannon were later made of cast metal, and when small, were portable or semi-portable; the smallest occasionally being fired when its supports were held in the hand. Next, an elongated breech-end, or tail, was fashioned, and the hand-gun resulted. Another way was to attach the hand-cannon to a piece of timber, the end of which was ledged upon the breast-plate of the gunner, whilst he supported the cannon on a forked rest; or, when the gun was small enough, he held it up with the left hand.

The small cannon of forged iron, attached to a wooden handle is the prototype of gun-barrel and gunstock. It remains but to add a holder for the slow-burning match, just a lever pivoted to the stock—the prototype of the gun-lock, and there is the gunstock, lock and barrel complete.

As " By hammer and hand all arts do stand," consider first the work of the smith as gunmaker. He forged the hand-cannon and he knocked out the S-shaped lever, or " serpentine," to carry the match in its notched upper arm. By pulling on the lower extremity of the lever, the upper arm descended, whereupon the glowing match ignited the powder in the touch-hole, or at a later date, in the " pan," which had a hole communicating with the barrel.

The barrel-smith and the locksmith conjointly produced two-thirds of the weapon. The carpenter's guild fitted the stock, and between smiths and carpenters there were intermittent feuds for the control of the trade of firearms production. All crafts had secret methods, so called " mysteries," not to be divulged. So long as the crafts continued as close corporations the mysteries have not been disclosed, and the methods, where known, have not been openly confirmed. Knowing what we know of blacksmithing we may examine the products of earlier periods critically and form our own conclusions as to the secrecy of the

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methods employed. Every unbiassed and competent critic will testify to the excellence of the workmanship generally. Hammer marks may often be detected on pieces of the mechanism and furniture, showing how close to the finished size each piece was forged. A goodly part of all blacksmithing is correct judgment, particularly of the size of the piece of metal to be used for the job—it is waste to cut off too much; worse to cut off too little. Amongst the special accessories required for gun work were patterns, so that any part of any weapon could be duplicated near enough for practical purposes. These patterns, which include gauges, jigs and gadgets—all three names derived from the same old French word " jauge, " by the way—were tools of trade of little use to anyone but the master craftsman who made them. A gunstocker who died some years ago left hundreds of " patterns " he had used, and could use, but for the majority of which no other gunstocker then working had any use whatever. In many cases the individual skill acquired by experience, and recorded by the work done, and for the workman himself in jotted memoranda on patterns, is sufficient explanation of many " mysteries " of various crafts. Such " mysteries " are difficult to impart to others than those persons—say apprentices—who have similar experiences and practical acquaintance with the same sort of work.

From the early 15th century to the end of the 18th century the general tendency of development of the gun-barrel was towards increasing its length and diminishing its weight. The object of the smith by using the best, that is, the strongest material, and the finest workmanship, was to produce a thin light *tube* which would withstand the bursting strain of firing with heavy loads.

The Spanish barrels for a long period had the highest reputation, because the Spanish blacksmiths of that period were as highly skilled as any in the craft and had the advantage of possessing excellent material. It was held—probably as the result of actual experience—that worn and used metal having been stressed was stronger than new. At any rate, old metal could be procured and used. In all barrel welding districts there was a demand for old horse-shoes, old coach springs, tyres, tyre-plates, and chains, but especially old horse nails. Horse-shoe stubs gave the name to a special figure of iron after the use of the stubs themselves were discarded. These articles welded one to the other made a strip easily hammered to the dimension required for a gun barrel skelp. The metal strip or skelp was not of uniform thickness, but more or less taper to give extra strength at the breech end. The skelp was then driven into a channel, that is, fullered or creased, so as to raise its edges which were then turned in to meet for a butt weld, or over each other for a lap weld, the channelling and welding work commencing about the middle of the length of the skelp.

The strip, or skelp, of iron was at first hammered out on the anvil by hand, later by a drop forge-hammer, or by machine power. Early in the 19th century

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skelps were rolled out. In 1806, John Jones, of Birmingham, patented a barrel made by twisting a skelp, having bevelled edges, round a mandril so that the edges overlapped for welding. Two years later Benjamin Cook made barrels by drawing the skelp through plates, or alternatively passing them between grooved rollers. Thus came the machine-made gun barrel, gas-piping, and other rolled tubes. The barrels were butt welded, lap welded, or they might be drawn. The nearest to perfection were the solid-drawn weldless steel tubes produced by W. Tranter, of Birmingham, about 1885, which were taper as well as perfectly concentric. Ordinary rolled barrels were made in the Midlands as late as 1909, but their production has ceased.

In the 17th century, barrels were stained russet instead of being " scoured " bright, thus revealing differences in the metals used in the same skelp. Then by choosing two metals, as iron and steel, for the same skelp, regularity in the difference could be secured, and " figured iron " was developed. The figure can be varied greatly. Piling iron, and steel plates alternately results in a figure called " Damascus," whilst if rods are piled alternately cross-wise or vertically, a figure known as laminated steel or stub Damascus results, and fancy piling will give any design—even lettering—if required.

On the Continent the barrel smiths, after making a skelp into a tube, wound round it spirally a riband of figured iron, then welded all together, the inner tube being bored out subsequently. In England it was not customary to use the inner tube, or *chemise*, but to wind spirally the skelp or riband of two to four skelps, and weld the coils together. The making of twist-barrels was discontinued in London about a century ago, and has ceased in Birmingham and the Midlands, the last barrels to be hand-forged in this country being those welded in the Greener Works in 1903. An attempt was made to revive this industry, but owing to difficulties with the iron, it was not successful.

The barrel welders worked in gangs of three, the master welder and two assistants; the chief manipulated the tube on the anvil, on a mandril, using a small hammer to indicate the part to be hammered by his two strikers. The three men used hammers of different weights, the heaviest being two-handled. The actual weld was made by the master welder by " jumping " the heated coil on a plate at ground level. As soon as this was done, by from 1 to 3 strokes, the work was laid on a grooved anvil, and the weld finished to the extent of the heat, say 4 in. to 6 in.; the barrel then required to be re-heated in the forge. The rhythm of blows was very musical and began with about three to the second, increasing to double that number when in full swing. The thick breech end was made separately and " shut " on to the longer fore part at what was called the " quarter round." After the barrel was completely welded it was reheated and

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hammered from end to end to bring it as nearly as possible to finished size. This was done on a grooved anvil and with a corresponding " set." The welder revolved the barrel continuously and held the " set " while the strikers hammered. The work was continued until the iron was black, as the metal was improved by that treatment.

The twist barrels were made in pairs, that is with a right and left hand spiral. These spirals or twists in the finished gun should diverge; when found converging, it may be assumed there was either a blemish to be hidden, or that the barrel filer was at fault in assembling them. A barber's pole pattern was occasioned by the mixing of the iron by the welder, and—if not discovered before making up—caused endless trouble to hide in the browning process; in some instances, however, a mixed figure was intentional, and unconventional.

Centuries ago the tube grinder, like the cutler, lay over the grindstone which turned towards him, if old prints are to be relied on. Grinding was a skilled craft; much grinding was done upon plate armour, and of course upon white arms and cutlery, but it is not generally known that it was a recognised process for the finishing of iron goods generally. In the 18th century the " dolly " method was followed for fashioning the flats on the breech-ends, and for the octagonal flats and " Spanish form " (16 flats) on rifle and gun-barrel tubes. The grinder's skill was so great that he could mill a tube as true to size and shape as any turner; say to within 0.003 in. in a diameter of 0.75 in. As against the turner and shaper (by planing, planishing, etc.) he had lower costs—water power, and hard stone, against the more expensive and less speedy steel tools of the turner. A grinder having the advantage of the broad surface of the grindstone could " true " a barrel quickly and well. A turned barrel needs much hand labour in subsequent " striking " or filing to give a good " shade " free from " rivels " and short inequalities. The grinders work was not confined to the tube, he fashioned also the butt plate and other pieces of the furniture, and the ramrod, and in ordinary work he could do more in less time than could be accomplished with a file, so he shaped and rounded the lock-plates of muskets, etc.

Other methods of producing a tube include drilling a bar, as practised from the earliest times; drilling a short bar, or block, and drawing out between rolls and on a mandril until of the length and thickness desired; and by drawing the metal, cold, into a seamless tube.

As to drilling little need be said. Sufficient that the old craftsmen knew the golden rule of spinning the work, not the drill. Tubes 36 in. in length have been drilled from the solid bar on an ordinary treadle lathe with the ordinary point of a flat drill. A machinist over a quarter of a century in the employ of the Greener firm, claimed to have driven a boring tool continuously on a foot-lathe for nearly

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nine hours, maintaining a uniform speed, for an uninterrupted cut from the time the job started until it was completed.

Since about the 15th century hand firearms have been weapons of precision, a few words on the actual performances of ancient arms may be appreciated. The Author has tested quite a number.[1] There are published details of what could be expected of a fowling piece in 1750, and as long ago as the 17th century Blome states:[2] "Shot flyeth as wide as about the compass of a bushell,[3] if rightly ordered in the charging." This is no guide, as no distance is given. With reference to rifles, the accurate shooting obtained is remarkable. Certainly the distances were less than those traversed by modern projectiles, but within the limits intended, they hit the mark, and altogether the tests make credible at least some of the wondrous feats of early marksmanship recorded in story.

Gunmakers have been experimenters, and progress has been through empirical methods. William Greener, a century ago decided the correct taper for a gun-barrel by thinning it down until the firing of a correct charge caused equal expansion of lead rings placed at different distances between breech and muzzle. Again, to test a theory as to work done upon ignition of a charge, he welded half a dozen musket barrels breech to muzzle, and so had a tube over 30ft. long for his tests.

Prior to the nineteenth century there were no muskets, fowling pieces, or guns of any sort which had barrels perfectly straight and level—except by accident. On more than one occasion, collections of old arms have been examined by experts to determine this question, and always with the same result. The barrels are approximately straight, but until a Birmingham fine-borer in the first decade of the 19th century discovered how to "shade" a barrel, it was impossible to detect any slight departure from truth in its bore. The method of straightening to correct any curvature discovered by the eye, was by striking the tube when laid on a block—a setting hammer being used. Another way was by cramps. In the schedule of the Arsenal of King Charles I., made by the Parliamentarians, are mentioned: "A great machine and a little machine for straightening barrels." The means for ascertaining if barrels were straight or not was by a master plug, or by a rod and the bow-string. There have always been calipers of special length for testing the thickness and concentricity of the walls, and these of the eighteenth century had multipliers, and a scale on a quadrant to indicate the divergence. The method of "shading" a barrel was demonstrated over 50 years ago, to the Birmingham master gun makers and the gun trade, by the late Samuel

[1] c.f. Appendix, p. 70.

[2] *Gentlemen's Recreation*, 1686.

[3] The standard bushel of the Manor of Birmingham in 1674 was 18¼in. diam. by 9in. deep.

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Smith, the gun barrel maker. He put a straight tube between supports, so that the shadow was thrown its whole length; then by means of a candle placed below the tube he procured a bend of the barrel whilst the shadow was under observation. A barrel is " set " or straightened on a hollow block, being struck on the bulging curve, or it may be " drawn " by hammering on an anvil on the inner side of the curve, the metal " drawn " lengthening the side and so straightening the curve, but if the metal thus hammered is subsequently ground or lightened and the hammered metal removed, the curve may return automatically.

Double barrelled guns appeared in the 17th century, just two single barrels one above the other, then side by side, but they were not soldered together until 1736. Later they were united by strips of metal lying between the barrels. The bottom rib had pipes to carry the ramrod. Then an elevated rib was used for the top junction. When it was hollowed both below and above, also tapered from breech to muzzle, it was said to be " Fullerd," after a London gunmaker (" Fullerd "), who was one of the first, if not the first, to use that type. With barrels of figured iron, a rib of figured iron to match was also used; this rib might be made of two rods of Damascus figured iron twisted in opposite directions, and welded together, the figure thus showing a middle line. This is mentioned as the rib-forger—extinct or practically so, with other of the minor craftsmen of the gun trade. We have now to get a strip of steel, taper it, and groove it above and below, with millers or planers its whole length.

There is still more to be stated about the barrel. At first the breech-end was closed with a " hut," then with a plug having a tail-piece; then the " tail-pin " (as it was named) took the same external diameter as the barrel to which it was fitted,—that is, it not only fitted the bore, but closed the barrel, being so fashioned as to be a continuation of the exterior of the barrel for about one inch, and was called a breech-plug. The " patent breech " was the conoidal base formed in the interior of the breech plug, and specially shaped funnels or holes communicating between barrel and " pan," or the " nipple " in which ignition was first induced, by flint, priming, primers, or percussion caps. Nearly two centuries ago, for conveniently removing the barrels from the stock, the former were attached by the lugs of the breeches hooking into a break-off, or standing breech, and a cross-bolt securing fore-end to barrels by passing through the " loop " of the ramrod " pipe." The " hooking " of the lugs and break-off was fine workmanship, and it was chiefly from the break-off fitters that the action-filers of later periods were recruited.

Gun-screws were (and many are still) of special threads. They all fitted well. The breech plug, when but one turn in, would not shake or permit of any lateral movement, but it could be turned in with thumb and finger the 10 or 12 threads which took it home, a wrench being required only to make the breech-plug bear

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at the bottom of the " cut " in the barrel and at the same time bed with its shoulder, or rim, bearing on the base of the barrel. All good gun-screws were thus " bottomed," that is, given a double bearing to prevent any loosening from the jars of firing and other use. The rule applied particularly to the breech-plugs, the nipples, and the tumbler-pins. The bigger threads were often formed with a chasing tool in the lathe and finished in dies.

In making screw-pins, " grinders " were used. The pins, etc., were hand-forged, knocked out by an " oliver," or treadle hammer, and some were taper. The forgings were ground down by forcing them with a breast-brace through a " grinder "; another grinder usually being required for the head, whatever its shape. Then the taper was put on by holding the screw in a hand vice and filing it whilst turning it on a steadier. A good smith was so adept at this that roundness was invariably secured, as also a uniform taper and the required dimension. The thread was then cut in a screw plate. In some instances, a gunsmith would cut any screw thread, any pitch or depth desired, simply by the eye, using the hand vice and file alone to effect the screwing. The smith made his own taps, often " slave," " first," and " full " cuts, from his own screw plate; he also hardened and tempered them.

Skilled hand work showed to greatest advantage in the lock mechanisms. These were of great variety, some simple, some intricate, and the best ornate. Every lock-filer had his own sets of templates, his jigs for " gaiting " the lock and for drilling the tumbler, the bridle and other pin holes, and for fashioning the parts. In all, a lock-filer's kit included over a score of special tools, of which the " grinders," " wheelers," " freers," and " shells " are probably almost unique. A filer could dispense with a lathe, and workmen have claimed that with a full kit of tools and patterns for the job no time was saved by resorting to the lathe. The forger of small-work for the lock-filer has disappeared, whilst lock-filing has all but vanished. However, we have still all details pertaining to the art of lock-filing, and, although full information has never been published, it is on record for use when needed. The fame of such lock-filers as Joseph Brazier, of Four Ashes, is as great as that of any of the gunsmiths of his day, and probably of any other age, whilst the workmanship of the locksmiths generally stands first amongst the handicrafts connected with iron and steel. The locksmith made and case-hardened his own patterns; made, hardened, and tempered the springs; he used only Huntsman's cast-steel, and charcoal iron, obtaining it from Sweden when British supplies failed. A tool-kit in the Author's possession comprised about 60 instruments, including " ovals," levellers, routers, saws, and special implements, but excluding a few dozen files of over a dozen sectional shapes, and sundry " vent " cutters for gaiting the lock mechanism. A " dead smooth " file, worn until

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almost a burnisher but still with " cut," is much prized even after 50 years of wear.

The lock-filer not infrequently was his own forge-smith. Hence comes the old witticism of the much stressed locksmith who, at 9 p.m., announced he " would knock off work now, and do a bit of forging "—that is, prepare the rough material for another day's work by labour actually harder than that of lock filing and fitting. Amongst the arts and crafts lost to the industry, that of the locksmith may soon be reckoned; practically gone already are furniture forgers and filers, cock forgers, nipple makers, ramrod smiths and turners, and most of the implement makers.

In all gun-work, as in many other crafts, what is called " setting " was an important detail. Mention was made of this in reference to straightening barrels, but the principle applied generally. It can be defined as giving the correct " lie " to any piece, by cramping, drawing, hammering, or similar process. In connection with metal parts it seems to have been achieved most often, either by hammering the metal, or whilst it was cramped or under pressure in the desired position, producing a jarring effect in the piece being set, by hammering, say the cramp or vice, and this resulted in the piece holding the " set " instead of returning to its former " lie " when released from the cramp. No hand process is equal to " setting " in connection with the production of high class fitting and qualities of durability in guns and similar articles. It is less practised than formerly, and may soon become one of the lost arts.

The barrel-smiths and locksmiths sent their finished products to other centres and to foreign countries to be mounted.

Gun-stocks are of various woods, but chiefly walnut, and were worked by carpenters and cabinet makers with the usual tools of their crafts, and taken collectively until the late 18th century, show work comparatively much inferior to that of the smiths.

When sportsmen required their guns especially made to fit them, with stocks not in line with the barrels but " cast-off " and with varying measures of bend and length, then the stocker had to devise fresh patterns, bend-jigs and measuring instruments, of which the " long middler " was peculiar to his craft. The stocker had to know the nature of the timber he worked, for gunstocks were often 4ft. and might be 6ft. over all. He first trued up the timber; then marked out, from a centre line obtained with the middler, the measured dispart of the barrel, then he grooved out the wood to half the depth of the barrel. Bend and cast off were spotted and marked; the stock shaped with draw-knife and plane, and the locks sunk. Special tools of the stocker included: Upright and other chisels, the tailed chisel or flute-tool, floats and fluting tools for barrel sinking, boring bits for channelling the ramrods; chisels, gauges, bottom-chisels or " shovels " for sinking the

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locks. The stocker used a torch for blacking, instead of the " smoking lamps " in use by all other craftsmen in the gun trade.

Each workman, or each group of master, journeyman, and apprentices, occupied usually his or their own private workshop, renting the same, with or without power, by the week. Into the workshop it was not etiquette to enter without first knocking at the door,—even by the master gunmaker in the factory of which he was also landlord. Each little shop might have the door fastened on the inside, or if, as in many cases, the only ingress was by a trap through the floor, a dog lay near. The methods actually followed in these shops were known only to the men working therein. Some of these craftsmen had ways of their own of getting particular results. If the work done passed " the view," questions were never asked as to how the end had been achieved. In most cases, of course, it was the individual skill of the worker, or by making the best use of the tools he had been taught to use to advantage. There were plenty of " mysteries "; recipes for welding fluxes, such as Stourbridge sand, etc.; browning and staining mixtures, for polishing wood and metal; methods of colour hardening; processes of hardening and tempering were as well and jealously kept as the concoction of the contents of the cooling trough in a forge, or of the hardening water used by the maker of hand-cut files.

The special tools used have been mentioned, but not the ways of using them. For instance, the breast-brace—a general tool—was used with a " stirrup," particularly when the cutting tool held was engaging both iron and steel in the same " cut." Lockmakers had their " stocks," and most fitters a " horse " or vice-rest, together with special clamps and fittings which saved time. Even in polishing, much depends upon manipulation, and good work was " stick polished " instead of being rounded on a " bob." Case hardening for colour is not due to " painting," as in other trades, but purely to firing in bone-dust—work coming to Birmingham from Liége and other centres for this process. Tone in browning is variable, not only with the mixture applied for rusting, but in the manipulation by previous polishing, liming, and intermittent scourings with wire brushes, and the like. It is also due to the iron from which the damascus was made.

It seems that the users of hand tools and workshop appliances made their own, or in using purchased tools found they could be altered to suit their particular purpose better. In the gun trade, with over a score of distinct crafts, tools were probably used in every practicable way. It may be that filing was originally chiefly draw-smoothing, as it certainly was upon barrels. Later, when the advantage of cross-filing was manifest, the " striker " for shave filing a tube longitudinally from breech to muzzle became the characteristic tool of the barrel-filer. Action filers and percussioners in fashioning parts made much use of cold chisels

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for knocking off the surplus from forgings, holes were drifted out to shape after being drilled.

Of cold chisels the gunsmith had a round dozen forms and as many sizes. There were many corners which, inaccessible to the file, were dealt with in a masterly manner. A cock of dainty form and proportions would take shape from the forging as if by magic, and what was more difficult its pair was produced—a right and left hand—and practically without a measurement being necessary, the work requiring the smooth file only to finish. On the breeches and fences, too, the cold chisel gives the form, the scraper often adding the finishing touches. Clean cutting was the characteristic of gun-fitting—even in engraving the attempt was to cut, never to scrape, rub, or scratch. The gun-workers differed from the engineers and fitters chiefly in starting work late in the day, and in working their movements were much quicker, particularly in filing, hammering, and the like.

With workers masters of their craft, each practising it in his own way, a high level of workmanship was attained, as the specimens preserved testify. It seems that the skill and experience thus developed are not transmissible under conditions which now prevail.

The masters of a past generation can supply the knowledge and directions required, but the workers lack particularly the knack necessary to adequate performance of various processes of manufacture practised in past periods. A learner can see a piece of steel fashioned to shape, heated red, plunged into water, and blazed off, yet may not be able to make a spring of the required shape, strength, and temper. We know that colours, polish, patina, and finish were produced in a certain way, the results often depending largely upon manipulation and less with the particular agent used.

It is with manipulation we are concerned. With the death of every one of these old timers special knowledge passes that will never return, because it is individual, and can only be individually acquired. It is the hope that we may be able to record—while there is yet time—some special hand processes, that the Author has ventured on this paper, and though he has not more than scratched the surface of the subject so far as gunmaking goes, it will, he hopes, stimulate effort in the same direction with other handcrafts.

To illustrate his paper, the Author made use of selected examples from his collection of smallarms that he had brought specially from Birmingham. From three exhibited rifles, the block (Plate XVI.) has been prepared, and to illustrate the tools used in the craft Plates XIV. and XV. are given.

Discussion.

Following the delivery of his paper, the Author said that he wanted to lay particular emphasis on the handiwork of the old craftsmen. It seemed impossible

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for anyone of the present generation to give a hand vice 60 or 70 turns per minute, but this was the kind of feat performed in the old days.

MR. T. CLARKSON mentioned an appliance made by William Driver, in order to overcome industrial troubles, etc., which were always arising amongst barrel setters. The apparatus consisted of a stand on which a barrel could be held, with a smoked screen and a light behind it. The screen had a circle scratched on it, and the diameter of this circle, in the proper ratio, showed the bore of the barrel. The work was in many cases carried out very quickly by girls.

SIR FREDERICK POLLOCK referred to the accounts given by Benvenuto Cellini of the wonders achieved in marksmanship during the 16th century. If these stories were correct, some wonderful shots were made at a time when gun-making was not far advanced. He would like to ask Mr. Greener how the people who used German guns knew that they were using the correct powder and the right charge, as they were surely not the same as the English. He did not think that the stories of shots with longbows of over 100 yards were correct.

MR. DAVID BROWNLIE said that he had always thought it a peculiar thing that Spanish weapons and armour should enjoy a far better reputation than any others. Even in "*Ivanhoe*," Scott referred to Spanish armour as being invincible. He would also like to know when rifling was first introduced. With regard to craftsmanship, he thought it a matter of the greatest regret that the handicrafts of old were dying out.

MR. MURRAY KENDALL thought that the introduction of rifling was a very interesting question, and expressed a hope that the author would be able to give the meeting a few points about it. Rifles were used in the American War of Independance, but it seemed very probable that these were made by Bohemian settlers in the backwoods. Turner says in 1665 that the Bohemians showed "excellency with the rifles." Sir William Temple, in his writings, states that the Bishop of Munster had a bodyguard 200 strong, armed with axes and screw guns which took bullets about the size of a pea. He would like to know what kind of machinery was used to get the pattern of the thread for the barrel. There was a book in which the different ways of making rifles in the backwoods were referred to. He was rather under the impression that in the mountain districts of Bohemia about that time, many little colonies of rifle-making people could be found, and perhaps they were the first to introduce rifles on the Continent. If so, was it possible that the Rifle Brigade established in 1800 was a result of this?

PROFESSOR P. M. BAKER said that he should like to support Mr. Brownlie's statement regarding the present-day lack of craftsmanship. The gun trade of England used to be the trade which showed the highest development of manual skill. His grandfather and father were gunmakers, and he remembered seeing them perform various operations with such dexterity as to obtain remarkable

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accuracy. One of the great dangers of the present day is that we are losing this dexterity. Englishmen could turn out wonderful work with up-to-date tools, but foreigners—especially the natives of India—turned out some wonderful work with simply the aid of hand skill. Some of the tools used by his father were of the crudest design, yet beautiful work was done with them. The beauties of this old handicraft, and the very apparent passing of it, seemed to be the chief lesson taught by Mr. Greener's interesting paper.

MR. H. T. BLANCH remarked upon the extreme awkwardness of the old rifles. It was necessary to carry at least three or four yards of match for firing, and about two feet of this had to be lighted at both ends. The lighted portion had to be put into the cock of the rifle and blown on, then put back to the left hand before the loading could be proceeded with. The introduction of the spring-operated flint lock was a great advance, as it had the firing apparatus attached to the gun. A much more powerful weapon introduced later was that known as the dragoon's carbine, which resembled the wheel-lock and the flint-lock. This was a sporting weapon used chiefly by peasants and gamekeepers. There was one point which he thought might be claimed for gunsmiths of the period, and that was that muskets were in use at the time of the Civil War. With regard to rifling, he thought that we could say that it was established shortly after 1600. At the siege of Geneva, in 1602, rifles (some of which are still preserved), were used. The date of the evolution of the rifle was, however, always in dispute.

THE PRESIDENT referred to the Author's remarks on grinding. He was rather surprised that in the 17th century grindstones should have been used for surfacing, as he was under the impression that they were only resorted to for sharpening purposes, etc. He would also like to know the manner in which the first barrels were bored. It was not easy to bore through wrought iron, and he was inclined to think that the first gun-barrels were made from unbored welded-up tubes. Did the expression " Fullering " come from the name of a London gunsmith? If so, it was interesting that a general smith's terms should be derived in that way.

MR. C. E. GREENER, in replying to the discussion, said that the object of his paper was not to deal with the historical side of the question—that would have taken far longer than one evening—but to endeavour to collect evidence of ancient handskill in gunmaking. Machine tools, we know, were little used, and the old handicrafts had quite disappeared from present-day practice.

With regard to Mr. Clarkson's remarks about Driver's setting device, a Frenchman had previously invented something similar, which threw the shadow of concentric rings down the barrel. During the late war it was found that barrel-setters could be taught the old method more easily than Driver's.

In reply to Sir Frederick Pollock's remarks, Benvenuto Cellini's statements were like many other chroniclers, more or less credible, but he referred to some of

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the exhibits of a somewhat later period to show what accuracy of performance was obtainable.[4] As to the charges of powder used, this was usually found by experiments of the user, and details of various practices were given by different writers, varying from ⅓rd weight of powder to shot to equal parts. It must not be forgotten that in these early days the powder varied greatly in quality and as to-day in every batch made. The master gunner was often the powder maker, and old writers stress the point that the charge be regulated to the *quality* of the powder.

Referring to the points raised about the introduction of the rifle, the author said that the invention of rifling dated a century earlier than had been mentioned by Mr. Blanch. It is variously attributed to Gaspard Kollner, a gunmaker of Vienna, in 1498, and to Augustus Kotter, of Nuremberg, in 1520. Rothsipen took out an English patent in 1637 for drilling barrels, rifling, etc. Spherical lead bullets were usually used in the 16th century rifles, which were at first straight-grooved.

As to Mr. Blanch's remarks, the general clumsiness of the old-time weapons, as compared with modern ideas, was attributable in the main to the dress of the period. A modern rifle would be very awkward to handle by the wearer of plate armour.

He challenged the statement that Spanish iron was of superior quality, and in the 16th and 17th centuries Masters of Ordnance tried Shropshire iron against various other iron. It was, however, proved that foreign metal was better, but he thought that it was probably the reputation it had established which had a good deal to do with its popularity, as there was a bigger demand on the Continent, especially for plate armour. Moreover, many of the leading gunsmiths were foreigners.

He thought that it was a likely thing that the American rifles which had been mentioned were made by German settlers in the backwoods, as the Germans had always been clever in the production of firearms.

In reply to the President's remarks, the earliest barrels were undoubtedly forged with a hole in, but we had no definite evidence of the tools used for boring. The grinder had "surface" worked for a long period, and in the 18th century the "dolly" method was already in use for removing more metal than the mere "washing" in which the work, if circular, is allowed to revolve against the stone. The "dolly" is a block—usually at the back of the stone—provided with a lever by which the work can be "scotched" and pressed against the stone. The lever is usually operated by the knee of the worker to get greater purchase.

The term "Fullerd" as applied to a gun rib, he believed, was named after a celebrated London barrel maker of circa 1790-1820, who supplied most of the

[4] *See* Appendix, p. 70.

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gunmakers with their barrels and ribs, as before that time ribs were made solid, and had little taper. A "Fullerd" rib was also a *fullered* rib, that is, was grooved and gave elevation, being also tapered. It is only gunmaking tradition which ascribes this form to "Fullerd," and it may have been the similarity of the name with the practice of fullered or grooved horseshoes of the general smith which led to the confusion. Certain it is that a rib was a "Fullerd," not a fullered one.

"Muller," or "Mullar," a grinder's term for grooving, was also applied to the "safety" edge surrounding the chequering on the wood which is sometimes practised to-day, and this has, of course, no reference to a name.

APPENDIX.

DIAGRAMS REDUCED TO HALF SIZE.

SHOWING RESULTS OF SHOOTING WITH OLD FIRE-ARMS.

ELIZABETHAN PETRONEL, with snaphaunce pyrites lock, c. 1600 (*see* Plate XVI, No. 1), one of the earliest rifles in the Author's collection.

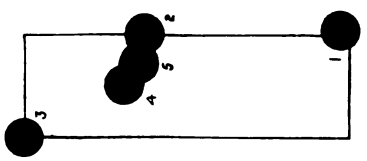

Fig. 1.
5 shots at 30 yards.

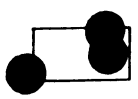

Fig. 2.
3 shots at 50 yards.

The barrel is rifled with 6 irregular grooves of 1 turn in 42in. The charge used was 1½ drams black powder and a spherical ball weighing 105 grains (0.383in. diam., about 82 bore). The velocity recorded at 20 yards was 1132. f.s. The penetration at 50 yards was 2½in. deal.

GERMAN WHEEL-LOCK RIFLE, by Hans Ruhr, Coburg, dated 1652 (*see* Plate XVI, No. 2).

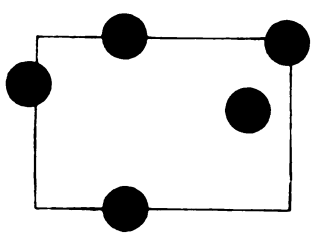

Fig. 3.
5 shots at 40 yards.

The barrel is rifled with 8 grooves of 1 turn in 56in., with small groove on land of rifling. The charge used was 60 grains powder and a spherical ball weighing 270 grains, 0.560in. diam., about 28 bore. The velocity recorded at 20 yards was 1429 f.s.

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American Flint-lock Rifle, by Hall, Harper's Ferry, dated 1804 (*see* Plate XVI, No. 3).

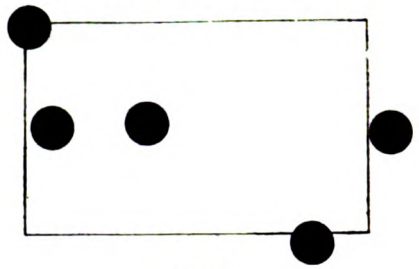

Fig. 4.

5 shots at 40 yards. Diagram half-size.

The barrel is rifled with 7 grooves of 1 turn in 54in. The charge used was 60 grains powder and a spherical ball weighing 225 grains, 0.542 in diam., about 30 bore.

Note.—The large touch hole caused unpleasant blow back upon discharge.

Diagram from a Modern Rifle.

Fig. 5.

10 shots at 50 yards.

Given for a comparison with the foregoing, except that the diagram is the *actual size*.

Calibre of rifle .310, firing 5½ grs. cordite powder and 120-grain solid lead conical-shaped bullet.

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Glass found in Egypt.

DESCRIBED BY

Prof. Sir Flinders Petrie, F.R.S.

(*Notes of a demonstration at University College, London, April 21st, 1925.*)

The earliest glaze known is that on stone beads of the Badarian age in Egypt, about 12,000 B.C. This is green. That civilisation was intrusive, probably from Asia. Green glaze was applied to a powdered quartz basis, for making small figures about 9,000 B.C., and was ever after so common on moulded beads that it was certainly of Egyptian manufacture.

The oldest pure glass is a moulded amulet of deep lapis lazuli colour, of about 7,000 B.C. Fragments of green opaque glass inlay appear in the 1st dynasty about 5,000 B.C. Striped black and white glass amulets come in the IXth dynasty, about 3,800 B.C. An elaborate fused glass mosaic of a calf is in jewellery of 3,300 B.C. from Dahshur. Blue translucent glass beads appear about 1,570 B.C. All of these occurrences of dateable glass in Egypt were probably due to importation from Asia, where glass was being made in Assyria in 2,500 B.C. As soon as Egypt overran Syria, artificers were brought in, about 1,500 B.C., and glass making became a flourishing and varied industry.

The composition of early glass was imitated in more than a hundred varieties of colour by Dr. Russell;[1] it is a blue silicate of lime and copper. Traces of iron render it green; hence blue glass can only be applied on a perfectly white base free from iron. The large scale production and temperature conditions were published by Prof. A. P. Laurie.[2] To get the finest colour long roasting of the material is needed, without rising to fusion: a small amount of potash or soda is needful as a solvent. The right temperature is 860° C., 30° difference is either too slow or makes a bad colour. Twenty-four hours roasting is necessary for the fine lazuli tint, such as was made in 7,000 B.C. The Egyptian managed this roasting by lining jars with a coat of paste to keep back the iron of the pottery, and then roasting balls of about an inch thick, stacked in the sealed jar. Furnace gases ruin the colour, and glazing was done in saggars, which were loaded, piled one on the other, and luted together. Straw was the only fuel, for the sake of its rapid burning. The furnaces were buried to retain the heat, with air holes facing the prevalent wind.

The largest early factory was at Tell-el-Amarna, about 1400 B.C. A great variety of coloured glazes were made for wall decoration and personal ornament.

[1] In Petrie, *Medum.*, p. 44.
[2] *Proc. Roy. Soc. Edin.*, Vol. 89, pp. 418-429.

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The frit was first combined in crucibles, where the quartz chips were slowly dissolved, and the carbonic acid thrown off by the limestone kept the mass as a spongy paste. When glass was made (with more alkali), it was left to cool in the crucible, and the sediment and scum were chipped away when cold. The lump of clear glass was then heated till it could be rolled into rods like a pencil, and then drawn down into thin canes. It was never worked in fusion, but pasty. Bottles were made by winding the cane on a sand core, applying bands of coloured cane, rolling them to the face by pressure, and finally polishing the face cold.

About 800 B.C. there was a large factory at Cumae, near Naples, where similar work was carried on, but with coarser colours and handling, and fused face for finish.

No blown glass is known till Roman times, but it was so abundant by 70 A.D. (at Pompeii) that it may have been developed during the previous two or three centuries. The old Egyptian glass mosaic of 1400 B.C. became commoner about 600 B.C., and was largely used by the Romans. Mostly it was made in a rod of unit pattern, drawn out thin, cut up, and the repeats of pattern placed together, and sub-fused on a waste-glass backing. Some of great delicacy was made without reduction, and delicate effects gained by slanting white glass through a base of clear blue, to give a shaded outline.

Glass was used for weights to test coins from about 300 A.D. in Egypt. This was carried on under the Arabs, and reached its highest accuracy in 780 A.D., after which it declined and became extinct by 1,300 A.D.

Reference for glass beads may be made to EISEN in *Amer. Jour. Archæol.* 2nd ser. XX, 1916, pt. 1: to LAVARD in *Archæologia*, 1907. On making glaze frit to *Ancient Egypt*, 1914, p. 186: Glass mosaic, earliest, in *Jour. Egypt Archæol.* 1920, pl. III.

The demonstration was illustrated by a large number of specimens drawn from the Museum of University College; a selection from these has been photographed and plates XVII. to XIX. have been prepared from them.

A vote of thanks to the Demonstrator was carried by acclamation.

DISCUSSION.

MR. NOEL HEATON congratulated Sir Flinders Petrie on the interesting way in in which he had marshalled and presented a great mass of information. Many questions arose in his mind but he would confine himself to two: *Firstly*, when did the transition from blue frit to true glass take place? The first named was a crystalline silicate of lime and therefore not a true glass. When was it discovered that by adding alkali, a viscous mass is produced? *Secondly*, was there not a period of transition before a real state of fusion was reached? There seemed to

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him to be a wide gulf between the fused glass and its utilization by blowing into various shapes.

MR. LOUGHNAN ST. L. PENDRED enquired if any tools used or the furnaces employed in this early glass making had been found.

MR. W. WORBY BEAUMONT said he did not wish to detract from the quite remarkable achievements of the early glass makers, but he would point out that it was difficult in some circumstances to avoid making glass, *e.g.*, glass had been made accidentally when a hot fire was made with wood fuel in a sand heap. The important thing to know was when control of glass began and when the furnaces or fires to effect it were introduced.

MR. B. RACKHAM was surprised to know that glass, as a controllable material, —*i.e.*, fused and capable of being blown—was so late as the 1st century of the Christian era. Early glass bottles appeared to be formed by moulding not by blowing.

MR. D. BROWNLIE had been struck by the statement that in 7,000 B.C. temperature had been controlled within 60° C. for a period of 24 hours. It was an amazing performance and he doubted whether it could be improved upon at the present day with all modern aids. He could not imagine that the temperature was uniform throughout, hence there could not have been many perfect pieces and the waste of material must have been excessive.

MR. E. W. HULME pointed out that there was an epigram by Mesomedes, the favourite of Hadrian, in the Greek anthology, which dealt with glassmaking *c.* 120 A.D. A note on the subject would be submitted to the Society shortly. The glassmaker starts with a glass block which he breaks into pieces and transfers one piece by means of a double forceps to the furnace. The glass emerges in a glowing trail—the workman trembling lest it should fall and break. The process here described is one of remelting glass for drawing into canes for millefiori work. There is no mention of glass-blowing. This supports Sir Flinders Petrie's statement that the older processes were not superseded by the invention of glass-blowing for some considerable period. Many people thought that glassmakers and glass-blowers were one and the same but the impression was quite wrong.

THE PRESIDENT in winding up the discussion remarked that glass-making was singular in that nothing led up to it; it was an entirely new art. Glass-blowing was an even more remarkable step.

SIR FLINDERS PETRIE replying to the discussion said it was not easy to answer Mr. Heaton's questions. It depended on what exactly was meant by the term glass; ordinary quartz could be said to come within the meaning. The earliest artificial material was glaze formed over stone. The first homogeneous manufactured glass was produced 7,000 B.C. and this glass lasted till the Roman period, say the 1st century A.D. when fused glass and glass-blowing appears; the

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production of the old kind of glass for mosaics lasted, however, for several centuries later.

In reply to Mr. Pendred, he could say that no very early furnaces or tools had been found, but at Tell-el-Amarna, 1,400 B.C., information on these points was very considerable. Shallow furnaces were used and glass made in saggars. He had found a piece of work as large as 5 ft high and 6 in. diameter made in this way. This was now at South Kensington. The pincers used for sampling glass were made no doubt of copper. Furnaces of Roman times had been found.

Regarding Mr. Brownlie's remarks, he was able to say that little material, judging from the waste heaps explored was wasted. Occasionally a whole saggar was found thrown out because it had been melted. He could only express the opinion that skill and care brought about the control of temperature; possibly the men worked in relays. It must be remembered that the skill exhibited by Egyptian workers was remarkable, *e.g.*, a granite sarcophagus had been found that had a surface that did not depart 1/250 of an inch from a true plane anywhere.

APPENDIX

VARIEGATED GLASS FROM EGYPT.

DESCRIPTION OF THE PLATES.

PLATE XVII. *Before* 1200 B.C.

1 Black and white layers, about 3500 B.C.
2-6 Stages of glass, 1400 B.C.; rough broken, rolled, drawn down, and flattened strip.
7 Pendant, black and white.
8 Earring of black, white, and blue glass.
9 Black, white, grey, green, and yellow.
10 Brown, white, blue, and yellow.
11, 12 Black and white.
13 Blue, white, and black.
14 Light and dark blue rim, black and white body.

PLATE XVIII. 1200 *to* 300 B.C.

15 Amulet figure, moulded pasty, buff; finally polished; such were of 1200 B.C. to 400 B.C.
16 Red glass with pearly iridescence, moulded and ground.
17 Yellow, black and white glass, Italian (?) about 700 B.C.
18 Yellow and black glass, later Greek form.
19 White stars in deep blue ground, built up.
20 Black and red rosettes alternating, in white, built up.
21 Nine strips of built-up pattern joined to form a kilt for an inlaid figure, buff, blue, red, and white.
22 White and red florets in deep blue ground, built up ready for a large group.
23 Red and black feather pattern.
24 Black, rosettes in blue, part of a dress.
25 Black, white, yellow, and red, built up of repeats of quarter of pattern.
26 Butt leaves in black.
27 Black, white and red in dark blue ground.
28 Black and red in yellow ground.

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PLATE XIX. 300 B.C. *to* 300 A.D.

29 Blue and white squares, brown and yellow flowers in green.
30 Green plant, brown and white flowers in deep red.
31 White in deep blue.
32 Green and yellow plant, and corn, red and white flower. in blue ground, not drawn down, but built of this size.
33 Green, yellow, and red plant; white and yellow, yellow and red flowers.
34 Blue and white layers.
35 Opaque blue and red layers.
36 Green and yellow bird, with red foot, in yellow ground, not drawn down.
37 Red and white flowers and green leaves, in dark blue ground.

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Chiddingfold Glass and its Makers in the Middle Ages.

BY

Brenda C. Halahan.

(*Read at University College, London, April 21st*, 1925.)

Before speaking particularly of the glass that was made in Chiddingfold, Surrey, I wish to give a very short history of the glassmaking families, whose names occur in local deeds, and in court and manor rolls. I must disclaim all first-hand knowledge about them, for their history was found out and written down by my father[1].

First in order of age, comes the Laurence family, whose family tree, as shown by local deeds, is given in the appendix. The first and best known members of this family in Chiddingfold was Laurence Vitrarius de Dunkshurstlonde, near Pockford, who in a deed of *c.* 1230 received a grant of 20 acres of land near Dyer's Cross, Pickhurst, for which he was to pay a yearly rental of 40d. and 1lb. of wax at the Feast of the Purification. In 1240, his name occurs in the Westminster Abbey records, as quoted by Professor W. R. Lethaby, as being one of those who provided glass, both white and coloured, to King Henry III. for his Abbey at Westminster. Apparently Laurence's two sons, William le Verir and Richard Laurens de Dunkshurst had an equal share of the holding Dunkshurstlonde (now Dunse farm) ; William le Verir, as his name shows, was a glassmaker, probably succeeding his father in the glass industry. His brother, Richard, is mentioned in 1307 in the deeds of the Abbey of Port Royal des Champs in France. It seems possible that the family was originally from Normandy, and they may have settled in Chiddingfold because of some still earlier glass tradition there, of which all documentary evidence has disappeared. Glass, probably unconnected with the Laurence family, was being made in the 13th century to the west of the Parish, at Chaleshurst, then known as Buthurst, and the holder, William de Buthurst was probably a glassmaker, though not mentioned as such.

I think that the furnace found in 1912 at Roaring Pond Copse was worked by the Laurences, for there is painted glass of their date from that site, as well as early white and blue window glass. The greater part of the window glass found there, however, belongs to the 15th century, when a later glass family, that of Peytowe from Poitou was supreme in Chiddingfold. It is not known if the French yeoman family of le Picard or le Picardy, of Pickhurst, combined glassmaking with farming in the 14th century, but it seems possible. Otherwise there is a

[1] c.f. V. C. H. Surrey, II, 295.

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break in the sequence of glassmakers known to us, from William le Verir, who died previous to 1300, till 1332, when there are two men mentioned as *glass dealers* in the parish; one of them, John le Alemayne, was almost certainly a glassmaker as well as a dealer. He had a holding of land called Alexander's, later Alemayne's, at the top of Hazelbridge Hill, and backing on to the big hanger and copse known as Fromes where an important furnace was found in 1921. John le Alemayne's name occurs, as a *dealer*, when, from 1352-1356, he provided window glass for St. Stephen's Chapel, Westminster, and St. George's Chapel, Windsor. The other Chiddingfold dealer, Richard Holmere, in 1352, provided 200 ponder of white glass, and 4 ponder of azure for the Chapter House, Westminster.

A little before this date, in 1343, another great glass-making family, that of Schurterre, is mentioned as becoming resident in Chiddingfold. The headquarters of the family was on some land to the south of the parish, Schurterrehurst—now Surreylands—part of the Shillinglee estate, where they had a dwellinghouse and furnace. But in 1368, the head of the family, John Schurterre, bought the Alemaynes holding near Fromes from the Alemaynes, who then disappeared from the parish, so it is probable that from 1368 onwards the Fromes furnace was worked by the Schurterres. They are not actually mentioned as glassmakers after the third generation at Fromes, as represented by Peter Schurterre, but they lived in Chiddingfold till 1610. I am inclined to think that they *were* glassmakers during the greater part of that period, for on the site of a farmhouse that they owned, I think in the 15th and 16th centuries, I have found late glass, crucible, and glass slag.

To return for a moment to John Schurterre, who probably worked at Fromes furnace from 1368 till his death in 1379. He was a glass-*maker*, not, I believe, a dealer as well. But it is in the latter half of the 14th century that the Dedyngtons, father and son, provided glass for William de Wykeham's educational foundations at Winchester and at New College, Oxford. They are described as "of Chiddingfold," but in Chiddingfold and Godalming records, their name does not occur. Therefore we must suppose that they *bought* glass from Chiddingfold, probably from John Schurterre, for the glass in the old windows of New College Ante Chapel can all be matched by fragments from the Fromes furnace. John Schurterre had, as well as his Chiddingfold glass interests, a furnace which he and a man called William Pikebosshe shared at Stroudwickswode, Ilford, in the Parish of Kirdfold, Sussex; and when Schurterre died, in 1379, his widow Joan made arrangements with a man called Glazewryght, from Staffordshire, to look after her share of this Sussex furnace, during her son's minority. The deed embodying this agreement, was signed at Plesstowe (Plastowe) in 1380, and the arrangement was that Glazewryght should work Joan Schurterre's moiety of the kiln at Shuerewode (Stroudwickswode) in the Parish of Kueredford for 6 years,

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commencing from Michaelmas of the previous year, and he was to receive for his labour, "for each sheu of brodglas (window glass) 20d. and for a hundred of vesselglass 6d." This furnace has not, as far as I know, been discovered, but if it were, the glass might prove of very great interest, side by side with that made at the same date, and by the same family, at Fromes. One reason that I have for supposing that the Schurterres continued to work there after the Peytowe family of glassmakers settled in Chiddingfold in 1435, is that the 15th century coloured glass of Fromes and of Roaring Pond furnace have small significant differences, which would hardly be the case if one family were working the two kilns. For instance, the 15th century ruby flashed glass from Fromes had generally a very thin flash of white glass outside a hair thin ruby flash, on a much thicker white body. I cannot remember an outer white flash to the ruby from Roaring Pond. Again, there were very many more *shades* of colours found at Fromes than at Roaring Pond Copse. If the Schurterres still worked at Fromes in the 15th and 16th centuries, it seems likely that the Peytowes were in possession of all the other furnaces that were then working in the Parish, with the exception perhaps of the Ropleys of West End, who appear to have produced both glassmakers and ironmasters. There were various branches of the Peytowe family, and the name varies in spelling, but originally they all came, I believe, from Poitou, of which their name is a corruption; just as it was supposed by my father that *Schurterre* was a corruption of *Chartres*.

Many furnaces in the district were closed down in the later days of the industry, for two reasons: (1) Because the iron industry was growing powerful in the district, and the iron masters used to tell tales and complain to the King, about the glassmakers for using so much timber; (2) Because English-made glass became unfashionable, and the parrot-cry was raised "Buy from abroad—it is *so* much better!" At least there was one glassmaker in Chiddingfold in the 16th century who was considered worthy of note by Charnock in his *Breviary* of 1557:

As for glassmakers they be scant in this land,
Yet one there is, as I do understand;
And in Sussex is now his habitacion,
At Chiddingfold he works of his occupacion:
To go to him it is necessary and meete
Or send a servante that is discrete,
And desire in most humble wise
To blow thee a glasse after thy devise:
It were worth many an Arme or a Legg.
He could shape it like to an egge;
To open and to close as close as a haire,
If thou have such a one, thou needst not feare.

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Charnock had evidently found this glass maker rather formidable, but it is not characteristic of Sussex men to go hat in hand to strangers, and this man was at the head of his craft, and obviously very independent. It may be that he worked at Fromes, where we have found glass as thin as an eggshell, though there are no fragments of vases with covers such as Charnock describes. The finest glass is naturally the most brittle, and when it is 2 ft. deep in a wet ditch, covered in with Wealden clay, leaf mould and débris, it is seldom in a condition upon which to build up theories. But you will see when you examine these fragments, which you must remember were their rubbish, that these glassmakers were men of very great skill. In this connection, you must take into consideration the conditions under which they worked. Their furnaces,—all the early ones certainly,—were built at, or near, the top of a steep copse, or hanger, generally with an outcrop or pocket of lower greensand near by, which they used, with wood ash as flux, for making their glass. And it is because there is so much iron in the sand that the white glass has such a greenish tinge. The only furnace that it not now a mound of disintegrated brick, is one at Salt Hanger. This furnace was built of weather tiles laid in courses, plugged with clay, and faced on the outside with sandstone. The main chamber was 9 ft. 6 in. long by about 6 ft. wide inside; this is where the fire was lighted. The small chamber 5 ft. long by 6 ft. wide, was subdivided up the middle by a wall of sandstone 12 in. thick, and further narrowed by having a double wall of tiles on the outside, so that there were two hearths for the crucibles, 5ft. long by 22 in. across, with tile floors and probably with brick arches. I think that, from what I have found in excavating other sites, that the kiln was generally built of lumps of brick, but these sites have been so much destroyed by copse-planting that they are now practically nothing but heaps of rubble. They seem generally to have faced N. in the hearth opening and S. in their length, and were surrounded by shallow ditches, with low banks outside! it is in these ditches and banks that the glass is found. At Fromes copse there were two main rubbish heaps, one to the N.W. and one to the E. of the furnace, in the ditches but there were other smaller pockets of rubbish on the banks, close to the surface, as though it had been thrown up from the ditches. It is at the N.W. rubbish heap that most of the 14th century painted glass has been found, but though so much window glass was found, there were very few painted pieces,—only one painted on coloured glass, though three pieces show traces of yellow stain.

The coloured glass comes under three headings:—*Potmetal,* that is, the same colour throughout; *Flashed or coated* with a very thin coat or flash of colour on a body of white glass; *Composite,* with a succession of colours which can be seen in the section of the glass, in all shades of grey and purple glass there are successive layers of red and blue. The green glass from Fromes is generally composite,

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sometimes in layers of white and green. But there were two tiny fragments unlike any I have found elsewhere. One was of three layers, lemon, green, lemon, in equal thicknesses. The other was in these proportions to the thickness, sapphire 1/3, lemon 2/3 with an outer green flash. On this green flash is a very thin ruby flash forming two red lines, when held to the light, and very thin ridge of *red paint;* which makes a dark green line when held to the light. As well as ordinary white and coloured window glass which is made as often of later bulls-eye glass as of muff or cylinder glass, I have found at Fromes, and at one or two other furnaces, some rough dark, very old pieces of bullseye glass sometimes with traces of a red coating, and I am told that this is 12th century glass, 100 years before we have any written record of glassmaking in Chiddingfold.

We have found fragments of tools and other things connected with the industry on the various sites, bits of leading, including a piece of finely worked lead-ventilator or wind break of perpendicular design; a glass pencil; a small glass tube, possibly a blow pipe for glass decorations; bits of iron blowpipes, iron closing-nails, and a small iron pickaxe, as well of course as glass-slag and pieces of crucibles. But perhaps the most interesting tools that we have found on the sites are the worked hand-flints which we assert were used as optional glass-cutters. The grozing-iron which pinched off the edges of the glass until it was the requisite shape leaving a bevelled serrated edge, was the usually recognised method of cutting. But we found glass obviously shaped, but with a clean-cut edge with no sign of grozing. Frequently these edges showed a curious feathering, and always I think a little roughening as though the glass had " sputtered " on contact with the tool that cut it. We found also curious scratches on the surface of the glass, which we were able to reproduce with the flints found on the sites. Then we found two or three small pieces of glass with, apparently, experimental cuts on them,—very deep grooves, feathered up both sides, and cracked below the groove almost through to the lower surface of the glass. We could see the shape of the groove, under a magnifying glass, to be of one caused by a rather blunt implement being brought to bear at an acute angle to the surface of the glass, and by tearing into the glass, causing the downward crack and the upward feathering. The groove, seen magnified, of a pointed iron as used in abrasion, is of quite a different shape; but a flint, being ill-tapered and relatively blunt, would naturally make a rather coarse groove. I have only found one flint, so far at Fromes Copse, but we found plenty at Roaring Pond Copse, and at Broomfield Hanger. We must be grateful, however, that, at Fromes, such an enormous amount of glass was left, as though the furnace was abandoned all standing, for a time. This may have happened at the time of John Schurterre's death in 1379, when his widow Joan must have been hard put to it, with glass-interests in Kirdford as well as in Chiddingfold. Labour, too, may have been hard to get, after the Black Death that

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swept Chiddingfold in 1370, and Joan may easily have closed down this kiln until her son was of an age to carry on. In any case, it proved fortunate for modern interests, for the fragments of vessel-glass that were left, though shattered, are all that remain to show what Chiddingfold glassmakers could do, and also to show the commoner sorts of vessel-glass then in use in England.

APPENDIX.

FAMILY TREE OF THE LAURENCES, DE DUNKSHURST, Nr. POCKFORD.

Laurence Vitrarius
(grant of land nr. Dyer's Cross, Chiddingfold, 1230 (Pockford deed). Provided glass for Westminster Abbey, 1240 (Lethaby).

William le Verir, m. Joanna
William
(to whom rent charge was paid on le Dunkshurstlonde in 1300)

Richard de Dunkshurst
first mentioned in 1279; in 1294 referred to as Richard Laurence of Chudyngfold; in 1307 mentioned as Richard de Dunkshurst at the Abbey of Port Royal des Champs in France. Owned the moiety of the Manors of Prestwick and Okelands in Chiddingfold.
Richard
(succeeded his father 1312)

LIST OF GLASSHOUSES AND SITES.

Glasshousefield and Glasshouse Copse, in Hambledon Parish, but near Dunkshurst, i.e. Dunsfarm, Chiddingfold (unexplored).

Glasshousefield, Redwode, S. of High St., some glass found.

Salt Hanger Glasshouse, Nr. Oldlands, S. of High St., kiln *in situ*, but little or no glass.

Fromes Copse Glasshouse, N. of High St., E. of Hazelbridge, remains of kiln, and much glass.

Roaring Pond Copse Glasshouse, c. ¼ mile W. of Hazelbridge, remains of kiln, and much glass.

Glasshouse Fields, Pickhurst, S. by W. of above, some glass.

Broomfield Hanger Glasshouse, Nr. Gostrode Farm, much glass.

Glasshouse Fields and Glasshouse Rew, Gostrode, W. of White's Hill, some glass.

Schurterre'shurst, now Surreylands, Shillinglee, E. of White's Hill, W. of Downlands, some glass, tiles, and crucible.

Chaleshurst Copse Glasshouse, Upper kiln, Nr. Ramsnest Common, much painted glass and window and vessel glass.

Chaleshurst Copse, Lower kiln, near stream in same copse, quite late glass, very fine quality, small quantity. Crucible containing red glass.

Ovenhousefield and Hovel Copse, W. of Chaleshurst, E. of Killinghurst, site of glass house in copse, excavated and demolished last century.

Site of Glasshouse, W. of Furnace Moor, E. of Imbham's.

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Glasshouse Field, Rodgate, between Anstead Brook and Cripplecrutch Hill, nothing to be found.

Kilne Copse, Combe Court, site of Glasshouse.

Glasshouse Close, Prestwick Manor House, near Ryestreet Common.

The paper was illustrated by a large number of specimens of glass excavated at Chiddingfold.

Discussion.

Mr. E. Wyndham Hulme said that the principal discoveries in the history of glassmaking made since the publication of Nesbitt's work in 1878 were those of Schuerman on the Altarist glassmakers, and of the late T. S. Cooper on the glassmakers in the Chiddingfold district. The latter's researches were happily being continued by his daughter Mrs. Halahan. With reference to the employment by the widow Schurterre of a Staffordshire glasswright—the term "glasswright" appeared to be the North Country equivalent of "glazier," an equivocal term which was subsequently replaced by the word "glassmaker." He identified the individual in question with John, the glasswright, who had made glass at Ulverston, co. Lancs., prior to 1351 but had gone elsewhere, probably to Staffordshire. Agreeing with Mrs. Halahan that the Wealden glassmakers came originally from France, he pointed out that Poitou was once a Gallo-Roman province noted for its extensive glass and ceramic works. Normandy at one time recruited from Poitou, and Altare from Normandy. The inter-relationship of the mediaeval glassmakers, however, was a very difficult question.

Mrs. Halahan's discoveries appeared to agree closely with those of M. Appert in his "Note sur les Verres des Vitraux Anciens," 1896, reprinted 1924. If so the Frome flashed glass must belong to the 16th century, and the Frome glassmakers must have kept in close touch with the practice of the French glassmakers. Appert's work, he thought, had never received the consideration it deserved. He hoped that Mrs. Halahan would be encouraged to proceed with her excavations.

Mr. Noel Heaton said that he considered that all interested in the history of glassmaking were greatly indebted to Mrs. Halahan for the researches described in her paper. It must have been no easy matter to piece together the evidence afforded by the scanty remains of the glasshouses of which, as Mrs. Halahan said, nothing but heaps of rubbish remained. Naturally, with such scanty remains a good deal must remain obscure in spite of the most diligent research.

Personally, he found it difficult to account for the presence of the fragments of painted glass—evidently portions of finished stained glass windows—amongst the débris of the glasshouse. It suggested that the Chiddingfold glassworkers were

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both glassmakers and glasspainters, a combination that was extremely unlikely. Even if one assumed such a combination, however, one was still faced with the difficulty of understanding how pieces of painted and fired glass came to be thrown away amongst the rubbish of the glass furnaces. He had discussed this matter with the late Mr. Cooper on several occasions, but they had never arrived at a satisfactory explanation of the presence of these fragments. The beautiful little window in Chiddingfold Church which Mr. Cooper had made up from some of these fragments shewed that they could scarcely be explained as spoilt pieces, thrown out presumably to be re-melted.

MR. J. A. KNOWLES said he agreed with Mr. Heaton that the discovery of fragments of grozed and painted glass on the site of a glass works presented great difficulties. For in mediaeval times glass-making and the designing and making of windows were two distinct trades, just as much as cloth manufacture and tailoring are now. The pieces of glass shown or described seemed to him to differ somewhat widely from existing specimens in mediaeval windows. The ruby from Frome, for example, said to be of the fifteenth century with a hair thin ruby flash was unusual. The flash on mediaeval ruby was generally a sixteenth of an inch or more in thickness.

In an earlier paper in the *Surrey Archæological Collection* on the Fromes Copse Glass-House, Mrs. Halahan had described glasses found there of a long range of tints of "violets, mauves, pink, purple, brilliant violet, imperial purple, and blue purple." But such a variety of shades was not to be found in mediaeval glass. The usual purple was of the typical pickled-cabbage tint derived from manganese.

The composite glasses presented a further problem. It was difficult to see of what use they can have been to stained-glass artists. The only object in having a flashed glass instead of a pot-metal, from a glass-painter's point of view, was that it enabled him to produce two colours on one piece of glass. Some of the glasses described consisted of four or more layers.

SIR FLINDERS PETRIE remarked that the source of the flints referred to in the paper was an interesting matter, as they appeared to resemble very closely those used by prehistoric people. Perhaps in the Chiddingfold district there was a field whence some of these flints came.

MRS. HALAHAN in replying to the discussion said: It would have been easy for the glassmakers to have found neolithic worked flints, as, by the number of worked flints found on high ground throughout the parish, it seemed probable that there was an extensive neolithic settlement there.

Was it not probable that John Glazewryth, who worked for Johannah Schurterre about 1380, was the son of John the glasswright of Ulverston, who

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would have been a comparatively old man to have started as a paid assistant, nearly thirty years after leaving Ulverston?

With regard to the coloured glass. This varied considerably in thickness, both in potmetal and in the flashed and composite glasses. The flash also, on ruby glass varied in the thickness of the flash, in one or two cases the flash being sufficiently thick almost to exclude all light through the glass. That was in a surface flash; but in the enclosed flash, *i.e.*, with a thin flash of white outside the ruby flash, the ruby flash was as thin as a hair. And the same was true of the green flashed glass. This outcome in the ruby could be explained in this way: a *thin* surface ruby flash appeared to have flaked off and decayed rather easily, for many pieces had been found at the glasshouses with only a fragment of the flash remaining, the rest having either disappeared altogether, or disintegrated into a soft, primrose-coloured decay. Therefore, to have the brilliant translucence of a thin flash, together with permanence, it would have been necesary to coat it with white glass to preserve it.

These glassmakers were, mainly, Frenchmen, who had with the purpose, one may suppose, of rivalling, and possibly ousting, continental glassmakers in supplying glass in England. This was, of course, pure conjecture, but it still happened in various industries. They would have experimented in colours,—as in the varieties in colour of purple composite glass, and also possibly in the thickness of the glass. A thin glass would of course be frailer than a thick one, and therefore it might more quickly disappear from church and cathedral windows, where the thicker,—short of vandalism—has been preserved. There were two instances of really thin fourteenth century glass which she had seen and handled, —some from the walled-up window of Chelsea Old Church, of which the glass, both white and coloured was very similar to some of the Chiddingfold glass, in both quality and thickness. The other was from a chantry, in memory of a crusader, at Slapton, in Dorset, which was entirely completed with glazing by 1377, and the glass which was dug up among the ruins was none of it thicker than the so-called sixteenth century glass from Chiddingfold. The many fragments of glass, of all sorts, found in the ditches of the kilns, probably were left there when the glassmakers, having exhausted the timber in one locality, moved on to another kiln.

Glass-painting for cathedrals undoubtedly was done by artists at the cathedrals, as quoted in the Westminster Fabric Rolls, probably under monastic supervision; but for village churches where simple and conventional grisaille glass was required, and the clergy were non-monastic, the requirements could probably have been fulfilled at the glasshouses. No fragments of painted *figure* glass have been found at Chiddingfold.

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Summer Meeting, at Gloucester, 1925.

The venue for this meeting was chosen because of its abounding industrial history. The district presents an epitome of those changes in the nature and the scale of manufactures that have taken place since Tudor times; indeed, if we include the Cotswolds we can say Roman times also. The headquarters were at the Bell Hotel.

First Day's Proceedings.

Thursday, June 18th.

This day was devoted to the Forest of Dean. The road out of Gloucester through Westbury and Newnham was taken, permitting charming views of the Severn estuary, on to Lydney, where the first stop was made to see the tin-plate works of Messrs. Richard Thomas and Co. The party was courteously received by the manager, Mr. W. H. Parry, and conducted over the works. Starting with tin bars—the raw material—the processes of shearing, heating, rolling into plates, doubling to reduce the plates to sheets, shearing and separating of the sheets, annealing, pickling, and cold rolling to give the necessary polished surface, were followed with close attention. The tinning of the plates by passing them through a bath of molten tin, protected by a layer of evil-looking compound, the squeezing off of the surplus tin, and the cleaning with "flour," proved to be of even greater interest. The sorting and boxing, principally for export, were finally seen. The Society's visit was obviously none too soon, as the machinery was in course of being replaced by more modern plant with labour-saving devices; in fact, a wholly automatic tinning machine was seen in operation.

The next visit was to one of the old iron ore workings in the Forest, known as the Scowles[1], situated between Lydney and Bream. (*See* Plate XX.)[2] Mr. H. G. Graves briefly explained the geology of the district and the occurrence, in fissures and caves in the lias, of veins and pockets of infiltrated brown hematite ore. Such a pocket was the Scowles, and it had been worked over a long period, possibly as far back as Roman times. Its fantastic appearance, as though affected by an earthquake, has been caused by subsidence. A good idea of its appearance will be gathered from our illustration. Some little excitement was caused when two of the party were found to be missing. It was feared they had fallen into the workings, but they had merely taken a wrong turning and fortunately succeeded in regaining the main body two hours later.

The drive from the Bream Scowles to Speech House, the next stopping place,

[1] The word scowles is Scandinavian in origin, meaning shelter or cover, c.f. Skeat. *Etymological Dictionary* and *N.E.D.*

[2] The block for the illustration of the Breams Scowles has been obligingly lent by Mr. Austin.

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was through Parkend, where the site of Parkend—coke—furnace, marked by the tall engine-house of the works, was pointed out. That it is still standing is due to the fact that it has been adapted by the Crown authorities for the purpose of a school of forestry. The site of Parkend tin-plate works was pointed out, as was also that of a works for pounding blast-furnace slag for the manufacture of glass. The probable site of Park—charcoal—furnace, in the seventeenth century, was indicated. The drive continued along the valley of the Cannop Brook, past two large artificial sheets of water impounded to supply water by a leat 1½ miles, and clearly visible on the hillside, to the water wheel installed prior to the engine to produce the blast for Parkend furnaces.

At Cannop Bridge is the conjectured site of Cannop Furnace, built in the seventeenth century. About a mile further on Speech House, a scene of sylvan beauty in the very heart of the Forest, was reached. Here in the Court Room, decorated with deers' antlers, luncheon was served. This over, Mr. Thomas Newcomen, very appropriately, because of his thirty years' residence in the Forest, gave a short account of the history of the house, dating from 1676-82, and of its use for the sittings of the ancient Court charged with the administration of the Forest. This Court, the members were glad to observe, is still held, as the following notice shows:—

> "The Verderers of His Majesty's Forest of Dean hereby give notice that the Court of attachment of our Sovereign Lord the King for the said Forest will be holden by adjournment at the Speech House in the said Forest at half-past three o'clock in the afternoon. . . ."

Mr. Newcomen was followed by the President who gave a brief sketch of the history of the iron manufacture in the Forest. There was evidence of the existence of the industry in Roman times, and he was of opinion that it was earlier still, and that since Roman times it had been carried on continously, only to become extinct within living memory. It was felt that the sketch was of such interest that it should be developed more fully for a subsequent meeting, and this the President agreed to do.

The route followed after leaving Speech House was by Raspidge, adjoining Cinderford, and by Littledean, once a great nail-making centre, to Gunn's Mills, in order to see the only vestiges, apart, of course, from slag heaps, of the charcoal furnaces in the Forest. The square shaft, with its openings, is intact, and on cast iron beams built into the furnace breast the date 1683 is visible. (*See* Plate XXI.) The right-hand side and the back of the furnace are buried in a mound of earth. On the left-hand side is the house, part of which is seen in the illustration for the water wheel and bellows. Sometime after it had ceased to be used for the production of iron, the furnace was converted for the purposes of a paper mill

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—a doorway was cut through it into the hearth, and above this a wide vertical slot into the body of the furnace. This slot cut through the cast iron lintel beams. The half timbered work at the top of the furnace seems to have been put up for the paper mill and the plastering of the front was no doubt done at the same time. Behind and to the left of the furnace is a brick-built house of considerable size which was erected when the paper mill was at work. A small part of this house is shown in the illustration.

A short run brought the party to Newnham, where tea was taken; the road thence to Gloucester was that traversed in the opposite direction that morning.

The annual dinner took place in the evening at the Bell Hotel, Gloucester, the guests being the Mayor of Gloucester, Mr. F. W. Duart-Smith, F.G.S., and the Librarian, Mr. Roland Austin. According to custom, no toast, except that of the King, was given, and no speeches were allowed. Later, the Mayor and Mayoress, supported by the late Mayor, Sir James Bruton and Lady Bruton, gave the Society a civic reception at the Guildhall. Records of the Trade Guilds of Gloucester from the fifteenth century were laid out for inspection in the Council Chamber, by permission of the Town Clerk, Mr. G. Sheffield Blakeway. An address on the Guilds: their ordinances, their rise and decay, was given by Mr. Austin, prefaced by some scholarly remarks on the history of the city from the Mayor. Refreshments were served and inspection of the documents followed.

Second Day's Proceedings.

Friday, June 19th.

This day was devoted to the Stroud Valley. The first stop was between that town and Stonehouse, at the Lodgemore cloth mills of Messrs. Strahan and Co., Ltd., where the party was met by Mr. H. D. Palmer and Mr. J. N. Todd, two of the directors. Here the process of making the well-known West of England cloth was seen. Breaking, combing, roving and slubbing of the wool, followed by mule spinning and doubling of the yarn, warping, beaming, weaving, scouring, teasling and finishing were clearly explained. At one stage was seen yarn for the notorious Oxford trousers. We gathered that the management would not for worlds discourage this voluminous fashion, although they did not themselves adopt it. All the machinery was driven in groups by electric motors, but at the Upper Works there was a beam engine, believed to be about a century old, but how old was not known, as it had come from another mill. Working at a pressure of 10 lb., it had been found to be inadequate to the work required, and had at some time been Macnaughted. One member was observed clambering about it in an almost loving fashion. Later a compound horizontal engine had perforce been

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added. The firm preserve an interesting letter[3] from King Charles to Prince Rupert, written during the Civil War, authorising him to commandeer all the cloth in the Stroud Valley for the use of his troops. How history doth repeat itself!

This interesting visit was brought reluctantly to a close because there was a further visit to make to the Thames and Severn Canal at Sapperton, its highest point, 363ft. above sea level, where a tunnel, 3,817 yards long, built in 1793, pierces the Cotswolds. Mr. Austin presented some notes on the tunnel, whence became manifest its great importance as a link between the inland navigations of the Midlands and the West of England. After the coming of the railway in 1841 its usefulness steadily declined; 1873 was the last year when it yielded a dividend, and in 1883 it was abandoned. Time did not permit of an intended visit to Thames Head to see the pumping engine which supplied the top level of the canal with water.

Cirencester was the next objective, as lunch was awaiting the party at the King's Head, an antient hostelrie. When the luncheon was over half an hour's grace was allowed. Most of the party visited the glorious fifteenth century church; the contemporary timber roof, owing to decay, was being repaired, and some of the beams were inspected as they lay on the grass in the churchyard.

A short run brought the motor to the Roman Villa near Chedworth, and again Mr. Austin acted as guide. The buildings are of considerable extent, such as would befit the residence of a Roman governor from the neighbouring city, but there was evidence in addition that the buildings had served some industrial purpose, the exact nature of which cannot be determined. Some large bars of iron,

[3] The text of this letter, which Messrs. Strahan have been kind enough to allow the Society to reproduce, is as follows :—

Charles R.

Most trusty and entirely beloved Nephew Wee greet you well Whereas Wee are credibly informed that at Cirencester, Stroud, Minchinhampton, Tetbury, Dursley, Wootton underedge and Chipping Sudbury great quantities of cloth canvas and Locherame are to be had for supplying ye great necessities Our Souldiers have of Suits, Wee have thought good to advertize you thereof And doe hereby pray you to send a competent party of Horse under ye comand of some able person to visit those severall places wch lye not farr asunder, and to bring from thence all such cloth canvasse and Locherame as they shall find there to Cirencester, Giving a Ticket to ye Owners for all ye parcells they shall take up and keeping a perfect Accompt thereof, and from what persons ye same was taken wth this intimation that every one of them shall upon his repaire to Oxford receave such Security for his comodity as hee shall have noe cause to except against. For ye better ordering and managing of this Service Wee shall expressly send Mr. Nevill, Mr. Bradburne & Mr. Ball men of experience, to take order for receaving and putting up of ye cloth whereof Wee intend ye best shall be reserved for ye service of our Troopers and ye rest for ye Dragoons & Foot of Our Army. In this we pray you to use yor wonted diligence. And bid you heartily farewell. Given at our Court at Oxford ye first day of February, 1641.

P. Rupert.

The year then ended on March 24th, so that in modern style the date is 1642.

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weighing respectively 480lb., 350lb., and 250lb., discovered in one of the out-buildings, have suggested that iron manufacture was carried on, but no evidence of this has been found. In those days iron was made by a direct process a single bloom at a time, and the bars therefrom weighed only a few pounds. The bars in question were evidently built up by welding lumps together. A similar bar weighing 340lb. has been found at the Roman station of Corstopitum in Northumberland.

Tea was served in the grounds *al fresco* and greatly enjoyed. After the return to Gloucester the party, now diminished in numbers, visited the museum under the guidance of the Curator, Mr. Charles Upton. Most notice was given to Roman remains, in which, as might be inferred, the museum is richest; but other objects, such as the remains of a " plank " ladder, *i.e.*, one cut from a solid plank and wooden shovels found in workings in the Forest of Dean, specimens of glass produced in the early glass houses of the county, &c., attracted attention.

The library was then visited, where early works on local topography and maps indicating the presence of industries were on view.

On Saturday morning the party, now seriously depleted, visited the Cathedral, where, as always, the early decorated work and the fine tracery in the cloisters aroused great admiration.

The weather throughout was fine and not too hot, for a " sweete breathing zephryus " . . . " lightly did delay hot Titan's beames which then did glyster fayre."

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Notes and Communications.

Letters of Marc Isambard Brunel.

Annotated by Rhys Jenkins.

A collection of ten holograph letters written in French, by the elder Brunel to the Duke de la Rochefoucauld in Paris, was presented in 1924 to the Institution of Mechanical Engineers by Mr. S. E. Alley. By the courtesy of the Council of the Institution, we are now able to present a short account of these letters with verbatim extracts.[1]

The letters range in date from November, 1814, to May, 1817, *i.e.*, the correspondence begins some months after the long war with France had come to an end, and Louis XVIII had been placed on the throne, and is interrupted by the return of Napoleon from Elba in March, 1815, with the ensuing state of war which terminated with the Battle of Waterloo.

A few words on the career of Brunel up to the period of this correspondence may be premised. He was born at Hacqueville, near Gisors, in Normandy, in 1769, and served in the French Navy from 1786 to 1792; in the following year he fled to America in consequence of the troubles of the Revolution, and in 1799 he came to England. In 1802 Henry Maudslay, who then occupied a small workshop in Margaret Street, Cavendish Square, commenced work on his block-making machinery for Portsmouth Dockyard. In 1810 Brunel turned his attention to machines for making shoes for the army.

The letters concern, in the first place, a steam engine and boiler made by Maudslay to the order of Brunel for the French Government, and intended to be applied to work a pump in the Conservatoire des Arts et Métiers in Paris. The engine was of a 8-horse power, and of the " Pyramidal " or Table construction patented by Maudslay in 1807.

In the first letter (11th Nov., 1814) Brunel informs the Duke de la Rochefoucauld that he has only just found out with certainty that there is no prohibition of the export of steam engines; the export duty will be 2 per cent. and the engine can be shipped to Rouen; he recommends the engine of Mr. Maudslay; the price is high, his 8 horse power engine costing £800 as against £630 charged by Fenton, Murray, & Co., of Leeds, but, on the other hand, the foundation will be less costly, and there is nothing to approach the quality of his iron castings, while the workmanship is careful and superior to anything of that kind that is done elsewhere.

[1] A transcript of the letters is in the possession of the Society, and can be borrowed by Members on application to the Hon. Secretary.

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In the next letter (5th Dec., 1814), Brunel acknowledges the receipt of one from the Duke, and states that he has given an order to Maudslay to put an 8 horse power engine in hand. He adds:—

> "Vous pouvez compter qu'elle sera bein soignée d'autant plus que je suis au moins 2 ou trois jours de la semaine employé dans les attelliers de Mr. Maudslay qui est chargé de l'execution de toutes les grandes machines que j'ai et ai eu pour le Gouvernement. Mr. M. dont l'établissement fait aujourd'hui l'admiration de touts les conoisseurs en Mechaniques n'avoit que trois ouvriers lorsqu'il a commencé avec moi il y a environ 12 ans, il a aujourdhui en outils et instruments nécessaires pour l'execution de machines pour plus de £25,000 sterling indépendement de ses batiments . . . On ne peut se former une idée de l'avancement des Arts Mechaniques dans ce pays cy."

Replying to a letter from the Duke, pressing for the delivery of the engine, Brunel writes (21st Feb., 1815) that it is not yet far advanced, the cause of the delay being that patterns have had to be made, this being the first engine of the size that Maudslay has constructed; many men would have had no hesitation in making use of the patterns of the nearest size, but he aims always at having the parts in proportion; the engine is promised for the 15th April.

This and some of the succeeding letters afford an interesting addition to what we know of Brunel's work at shoe-making by machinery. There was a great demand for shoes for the army, and Brunel in 1810 obtained a patent (No. 3369) for "Certain machinery for the purpose of making or manufacturing boots and shoes." He was concerned with shoes of the kind in which the soles are fixed to the uppers by pins or nails, and his specification describes a machine for piercing the holes and driving in the nails (probably the first nailing-machine ever devised). In this machine the upper is clamped on a last, the inner sole is laid over its edges, and the outer sole superposed and clamped. The holes are pierced, one by one, by an awl on a treadle-actuated plunger, which also forms a hammer to drive in a nail inserted by hand in the previously formed hole. The specification also describes apparatus for cutting the soles and heels to shape, in which the leather is clamped between two former plates and is cut by a hand-knife run along their edges.

It would appear from what is said by Beamish[2] that Brunel devised a complete system, in which the manufacture was divided into sixteen processes, including punching, tacking, welting, cutting or trimming, and nail-driving, and that the manufactory set up, 1812-14, employed 24 men and was capable of producing 400 pairs of shoes daily. It is to be inferred that Brunel had rivals in the factory production of shoes, for in his letter of March 6th, 1815 (*see* below) he states that

[2] *Memoir of the Life of Sir Marc Isambard Brunel*, 1862.

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all the attempts made by others had failed completely, and that at that date his establishment was the only one that remained. Of these attempts we have no information, but it is known that, twenty-five years earlier, Thomas Saint had patented a machine for sewing shoes, and the use of nails for fastening the soles to the uppers was patented by D. M. Randolph in 1809, as a communication from the United States.

With the termination of the war the demand for army boots ceased, and Brunel's project collapsed, with considerable loss to himself.

To resume the consideration of the letter of 21st Feb., 1815: Brunel therein makes a long statement about his negotiations with the French Ministry of War in regard to shoe-making machinery. He opens with the remark that he does not know on what point the officials of the department can complain of his terms; he had been requested to send over machines and workmen, the cost of transport to be paid. Had he made advances of machines and men upon such a request, where would he have stood? He considered that it was necessary to reach a definite understanding first, and in order to avoid too great expense went over to Paris. Instead of attending to his own concerns, he gave himself up entirely to this, and remained in Paris at the disposal of the Minister so long as it was in his power to do so. Then, seeing that it was not the intention to have the machines, he claimed his expenses on the same scale as he is paid in England, *i.e.* five guineas a day independently of his disbursements. He is prepared to treat with the French Government, has experience now of some thousands of pairs of shoes —above 100,000—has attained an end hitherto deemed impracticable, that of repairing shoes of this sort, and has demonstrated and convinced the government that the shoes can be repaired by the soldiers themselves. Perhaps, he says, the Minister is ignorant of the extent of his enterprizes here, and pictures a shoemaker with ridiculous pretensions. He confines himself to saying that if, as a Frenchman, he has been charged with operations so extended as those that he has conducted in the Naval Arsenals since 1803, it has been necessary to give some proofs. Then, in a postscript, Brunel tells the Duke that if he meets any of the officials of the Ministry of War he may assure them that he (Brunel) is ready to treat with the Government, but at the same time there must be some advantage to himself. Possibly they found the price of the shoes he sent too high, he had asked only what had been accorded to him here in competition with others. Perhaps also they were alarmed at his expectations for the future, for in the course of conversation he had mentioned that he had received £17,000 sterling for a single invention and £4,500 for a second, some days before his departure for Paris. Brunel goes on to say that *The Edinburgh Review* for the last quarter of 1814 mentions that he had received £20,000. This is true, if there is added to the first sum about £3,000 paid for his expenses during four years. The Editor of the *Review* expressed the

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opinion that had the sum been doubled it would not have been too much. These statements had perhaps frightened the officials of the war department, but as everything has its value, he is paid only because he is good for something, in spite of original sin.

In his next letter (6th March, 1815), Brunel says that he cannot abandon the subject of shoes without making some additional remarks. The officials of the Ministry of War, after having asked him for the machines, limited themselves to about 300 pairs of shoes, without offering him the least compensation and even without communicating the views of the Government on the results. The first trial made here for the Marines failed completely, while success followed in a trial by a line regiment—that was due to particular circumstances. Since then the general of the first corps has forwarded a very satisfactory report with congratulations. He has, in addition, other reports which surpass his expectations. There are at present in Chelsea Hospital soldiers returned from Spain who still wear the same shoes; others have followed the campaign up to their embarkation at Bordeaux and have still the same shoes. It was not all to have succeeded thus far, it was necessary still to be able to repair, which has always been a great difficulty. He has proved that a man can easily resole his shoes. He flatters himself that he has succeeded in producing a shoe particularly suited for the army. Others may succeed, but if they experience as many difficulties as he has had to surmount, they will have plenty to do. He does not hesitate to say that had he not been so well known by the success of his other inventions, public opinion would have turned against the object, for all the attempts made by others have failed completely. To-day his establishment is the only one that remains. It grows every day, and will in a few weeks present a very satisfactory appearance.

Before the date of the next letter (26th March, 1815), Napoleon had returned to France and Louis XVIII had fled. Maudslay ceased work on the engine, possibly on Brunel's instructions.

Early in the following year the correspondence is resumed, and Brunel (6th Feb., 1816) sends the Duke a copy of a letter from the Maudslay firm stating that the engine "was about half finished last Spring, when the work was stopped. We are ready to resume it upon an order to that effect, and no time shall be lost in getting it ready." In regard to the shoe-machinery, Brunel states that as the government of this country is not taking any more of his shoes for the army, he is not making a great thing of it. He has spent about £15,000, and does not know how he is to get a return; has the buildings, the machines, and an assortment of shoes on hand. The more they are known the more highly they are valued, and the demands of the public are constantly increasing; he has no doubt that it would be a good investment for a man with capital, but as for himself he cannot confine

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his energies to shoemaking. He learns that Mr. Olivier is now making shoes in Paris on a principle similar to his own.

On 24th Dec, 1816, Brunel writes in reference to the forwarding of the engine, and on 25th March, 1817, he informs the Duke that it has been sent to Rouen, and that one of Maudslay's sons is now in Paris, and has been to the Conservatoire des Arts et Métiers to see the place in which it is to stand. Brunel suggests that as the engine is a beautiful piece of workmanship it would be well to place it in one of the model rooms.

In his next letter (15th April, 1817), Brunel expresses the hope that the engine will arrive in Paris in good condition; he is just sending off a 16 horse power engine to Rheims. He refers to a recent boiler explosion, and mentions several earlier ones, and adds that in America, in spite of two accidents, steam boats are making great progress. He is sending three engines of 25 horse power to Montreal and Quebec for steamboats—one of the boats has cost 160,000 dollars. He is about to make some experiments with steam tugs for ships of war. A little bill for extras in connection with the engine is sent with the letter; it includes a sum of £40, being Brunel's commission at 5 per cent.

This charge for commission the French officials took objection to, and in his next letter to the Duke (26th May, 1817), and the last in this collection, Brunel says that he cannot help contrasting the observations of the Minister with those of certain manufacturers in the environs of Paris to whom he had just sent an engine. (The reference seems to be to the 16 horse power engine for Rheims, the boilers of which were sent over in the same ship as the 8 horse power engine.) These gentlemen had thanked him for the moderation of his charge for the same work, and that without enquiry as to the circumstances or any other observation, being fully persuaded that he had given himself a certain amount of trouble about the construction of the engine. He goes on: " I admit that Mr. Maudslay would have acquitted himself very well without my inspection, but I am pleased to think that a man who, in consequence of my inventions, finds himself the owner of a fortune of more than 1,200,000 francs will treat me better than any other persons. I beg of you to explain to the Minister that I am neither merchant nor agent; I give myself the trouble of following up work of this nature that is confided to me." This, the last letter of the series, concludes in a strongly personal key, and it will be best to use Brunel's own words:—

> " Je ne puis m'empêcher de refléchir sur les réclamations qu'on m'a tant de fois fait, pour me rappeller dans ma patrie à qui, dit-on, je dois mes talents et mes services. Combien de compliments flatteurs nai-je pas reçu sur ce point. Monsieur Le Duc d'Orléans, Madame La Duchesse etc., et bien d'autres. Le premier et toute sa suite en voyant dernièrement mes travaux dans l'arsenal de la Marine de Chatham voulaient, pour ainsi dire, me faire

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promettre de revenir en France. Ce seroit un sacrifice bien inconsideré de ma part si j'allois abandonner tout sans aucun dédomagement, si j'allois sacrifier ma famille pour un principe si chimérique. J'ai reçu environ 500,000 francs pour une seule de mes inventions—et plus de 100,000 pour une autre sans compter la paye que je reçois pendant le cours de mes entreprises. Lorsq'appellé, il y a environ deux ans et demi, j'expliquai au Ministre de la Guerre que mon séjour à Paris me faisoit perdre cinquante écus par jour que je reçevois du Gouvernement Anglais, indépendemment de mes autres affaires, on m'a bien fait sentir, alors, qu'on ne pourroit jamais me dédommager, aussi n'ais-je rien reçu du tout. J'en ai eu pour ma peine, voyage, etc., qui m'a couté plus de deux cents guinées. Le Gouvernement étoit alors infiniment moins obéré, qu'aurais-je donc a espérer si j'allois offrir mes services à ma patrie qui ne me reclame que parceque je pourois être de quelqu'utilité sans même m'assurer un salaire honorable. J'avoue que je ne suis pas sans éprouver quelques difficultés depuis que l'économie est à l'ordre du jour. J'ai beaucoup moins à faire qu'autrefois, cependant on ne me dispute pas mes appointements, et si on en venoit à ce point j'ai encore beaucoup d'autres ressources. Invité par d'autres gouvernements, je me flatte que si je voulais devenir un cosmopolite, je pourois m'assurer d'avance des avantages assez considérables; mais heureusement je n'en suis pas encore réduit à ce point. On sait ici combien j'ai été flatté et invité par l'Empereur Alexandre: il n'y a pas un artiste en Angleterre qui puisse se glorifier d'attentions aussi distinguées et aussi publics que celle dont sa majesté m'a honoré en presence de touts les Princes souverains que l'on a fêté dans ce pays ci. Si un Français qui n'a jamais appartenu au corps de Génie de France est parvenu a acquérir une telle considération, on ne poura l'accuser de vanité s'il attache un certain prix à des talents dont on a su tirer parti dans ce pays ci. Si vous avez occasion de voir son Altesse Monsieur de Duc d'Orleans, veuillez bien lui demander de vous rendre compte des ouvrages de Chatham et vous pouvez alors satisfaire le Ministre sur l'importance de mes occupations."

It is just possible that, in regard to his dealings with the French government, Brunel may have been unfortunate in having the Duke de la Rochefoucauld for his friend in Paris. The Duke was a prominent man, and very active in public affairs, he was Inspector-General of the Conservatoire des Arts et Métiers, and held a number of other unpaid appointments, but he seems to have been more of a French patriot than a Royalist, and he was not in favour at the court of Louis XVIII. He was a man twenty years or so older than Brunel, and it is not known where the latter made his acquaintance, possibly it was in the United States, where the Duke was travelling in 1795-97. His interest in industrial affairs is shown by the fact that as early as 1790 he had set up a cotton-spinning factory at Liancourt.

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Recollections of American Railroads fifty years ago.

BY

William H. Truesdale.

(*Communicated, March,* 1926.)

The development of the railways in the territory west of the Allegheny Mountains began shortly after the close of the Civil War, or about 1870. At the time I first entered railway service, in 1869, the total mileage of the country's railways was about 53,000 miles.

The first transcontinental railroad was the Union and Central Pacific Companies' line from Omaha to San Francisco.

Tracks were laid with ridiculously light iron rails, poorly tied and with inferior ballast. Bridges were built of timber, and stations and other buildings were constructed of the same material and were primitive in every respect. Grades were very heavy, following closely the topography of the country through which the roads were built, with narrow cuttings and inadequate embankments, in order that construction costs should be low and commensurate with the capitalization of the roads.

Locomotives of that period were of small capacity and low tractive effort. Passenger coaches were (on the same scale) built entirely of wood, heated by wood-burning stoves and lighted by candles, coupled by the old link and pin couplers, while trains were controlled, as to speed and stoppage, by hand brakes. Freight cars were of about the same character, with a maximum capacity of 12 tons, and equipped similarly to passenger cars as to couplers and brakes.

In those days engineers and firemen were assigned to a particular locomotive, and whenever repairs were necessary those employees were utilized, to a large extent, in making such repairs. It was quite common, also, on passenger trains, the locomotives of which used wood for fuel, to have the trains stop at points between stations, where the farmers in the neighbourhood had cut and piled wood for the railroad company's use, when the passengers would turn out, together with the engineer and trainmen, and " wood up " the locomotive.

Passenger trains at that time rarely exceeded a speed of 20 miles an hour, and this was largely when they were running down a more or less heavy grade, the idea being that the momentum of the train going down the incline would help the engine in pulling it up the other side.

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The Allegheny Portage Railroad.

An interesting feature of the Central Pennsylvania Meeting of The American Society of Mechanical Engineers at Altoona, Pa., on October 5-7, 1925, was the visit to the site of the Allegheny Portage Railroad, over the Allegheny Mountains, constructed in 1834 to link together the Eastern and Western Divisions of the canal system from Harrisburg to Pittsburg.

On October 6th, the day selected for the excursion, a party of 150 boarded a special train at Altoona and proceeded to inclined Plane 8, the middle one of the five planes on the eastern slope. Here over half of the party detrained and, under the leadership of William Elmer, Superintendent of the Middle Division of the Pennsylvania Railroad System, plodded in single file up the incline to the level between Planes 8 and 7, undeterred by a gentle rain that was falling. Trees had sprung up on this former busy path of trade, and undergrowth hid some of the evidences of construction, but otherwise it was just as it was when the planes were abandoned in 1855, after being in service for 21 years. At some places the terrain dropped sharply at one side and rose vertically on the other, showing that the construction of this inclined shelf on the mountain side had been no simple matter. At intervals the party gathered around Mr. Elmer, who pointed out the stone blocks that supported the rails,—some uncovered of moss and leaves for the occasion,—the ruins of the foundations of the hoisting engines, and of the great pits for the sheaves for the haulage ropes. It became easy to visualize the early days with the straining ropes, the protecting strap-bound wooden stringers, and the puffing steam engines hauling up the loads of goods and west-bound pioneers. As the party emerged into the level open space between Planes 8 and 7, the sun came forth for an instant and the explorers were favoured with a glimpse of mountain scenery and autumn foliage that was worth all the toil. Far below was visible the newly built William Penn Highway that parallels the Old Portage and as one looked down at the lumbering motor trucks and speeding cars on its smooth, concrete surface one wondered what in another seventy years would be considered up-to-date transportation. The return to the train was made in a spirit of appreciation of the pioneers who built the Portage and operated it successfully.

C.E.D.

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Memorial to Charles Wheatstone.

The City of Gloucester, the birthplace of Charles Wheatstone in February, 1802, honoured itself on October 19th, 1925, the fiftieth anniversary of his death by placing a bronze memorial tablet to his memory on the exterior of the N. wall of the nave of St. Michael's Church. The tablet was unveiled by Sir Charles Sherrington, President of the Royal Society, in the presence of a distinguished gathering.

Wheatstone began life as a musical instrument maker. He is remembered with Sir William F. Cooke as a pioneer, as far back as 1837, of the electric telegraph which together they made an assured success. In 1844, Wheatstone conducted some of the earliest experiments in submarine telegraphy. Probably he will remain known longest, to electricians at any rate, as the perfector of the Wheatstone bridge which is in every day use. In 1867 he invented the self-exciting shunt wound dynamo. By physicists, Wheatstone is well known for his rotating mirror to detect whether an electric discharge is oscillatory or not. He made researches in sound and it is not common knowledge that the English concertina was invented and patented by him in 1829. In regard to light he made the important observation that sparks between metals give distinctive spectra.

One of Wheatstone's recreations was the solution of cipher writing for which he had a great gift. He invented the cryptograph for mechanically coding and decoding messages.

Wheatstone was appointed professor of experimental physics at King's College, London, in 1834, but seldom lectured after 1840; to it he bequeathed his library and apparatus. His family included the Patent Office Museum in the distribution, and apparatus of his is to be seen to-day in the Science Museum, South Kensington.

Wheatstone was elected a Fellow of the Royal Society in 1836 and received many honours, including that of knighthood in 1868 for his services to electrical telegraphy. H.W.D.

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Subject List of Books and Pamphlets
Relating to the History of Technology, Published during the period, 1920-1925.

The following list is based on the Catalogue of the Patent Office Library, and all works entered with an asterisk can be seen in that Library. For foreign works not so available, the publisher's name is given, and, wherever possible, a review notice is indicated. Entries are arranged in chronological order under each heading. I have to acknowledge the help of Mr. E. W. Hulme and Mr. W. E. White in the preparation of the list.—A.G.

General Works—Antike Technik. Von Hermann Diels. 2te Aufl.—*Leipzig, Teubner*, 1920, 251 pp. 18 pl. frontis.
Chapters on Greek science; ancient doors and locks; Hero of Alexandria; artillery; clocks; ancient telegraphy. 1st ed. 1914; 3rd ed. (reprint) 1925.

——— *A classical technology. Edited from Codex Lucensis 490 [with transcription and translation] by J. M. Burman —*Boston* [1920], 8vo, 170 pp.
An 8th Century MS. of receipts, etc.

——— *Die Naturwissenschaften in ihrer Entwicklung und in ihrem Zusammenhang. Von Fr. Dannemann. 2te Aufl. —*Leipzig*, 1920-23, 4 vols., 8vo.
1st edition, 1910-13. 4 vols.

——— *An address of thanks to the members of the Engineering Societies of the United States, June 29th, 1921, by Sir Robert A. Hadfield.—*London*, 1921, 8vo, 48 pp. 8 pl.
Section IX. treats of the growth of science and the work of the Royal Society since 1662.

——— The age of invention. A chronicle of mechanical conquest. By Holland Thompson. (The Chronicles of America). —*New Haven, Yale University Press*, 1921, 279 pp.
Beginnings of U.S. patent system; cotton gin; textile machinery; rubber; machine shop; electricity; aeronautics. "Popular but of the best kind."—Isis IV., 1922, p. 517-19.

——— *Erfinder und Erfindungen. Von A Neuberger.—*Berlin*, [1921], 8vo, 284 pp. 36 pl.

General Works—*continued.*

——— Esquisse d'une histoire de la technique. Par A. Vierendeel.—*Bruxelles, Vromant*, 1921, 2 vols., 8vo.
Reviewed in Isis V., 1923, 486-7.

——— A history of industry. By E. L. Osgood.—*Boston, Mass., Ginn*, 1921, 437 pp., 8vo.

——— *Studies in the history and method of science. Edited by Chas. Singer.—*Oxford*, 1917 etc., 8vo. (*In progress*).
Vol. 2, 1921. Greek Biology; Mediaeval Astronomy; Roger Bacon; Leonardo as anatomist; Galileo; Invention of first optical apparatus; Archimedes' principle of the balance.

——— Die Technik des Altertums. Von A. Neuburger. 2te Aufl.—*Leipzig, Voigtländer*, 1921, 8vo, 588 pp.
Practically the same as the 1st edition, 1919. *See* criticism of this by Feldhaus in Geschichtsbl. f. Technik VI., 1919, pp. 120-137. A third edition, unchanged, was issued in 1922.

——— *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern. Von Hans Schmeller. (*Abh. zur Geschichte d. Naturwissenschaften u.d. Medizin, Heft* 6).—*Erlangen*, 1922, 8vo, 52 pp.
Perpetual motion, water wheels, etc.

——— *Der Siegeslauf der Technik. Von M. Geitel. 3te Aufl.—*Stuttgart* [1922-24], 3 vols., 8vo.
First edition, 1908-09.

——— *Der Werdegang der Entdeckungen und Erfindungen. Von Fr. Dannemann. Heft 1. etc.—*München*, 1922, etc., 8vo. *In progress.*
Heft 1.—Die Anfänge der experimentellen For-

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General Works—*continued.*

schung und ihre Ausbreitung. Von. F. D., 1922, 36 pp.

Heft 2.—Die Astronomie von ihren Anfängen. Von E. Silbernagel. 1925, 68 pp.

Heft 3.—Elektrische Strahlen und ihre Anwendung (Röntgen Technik). Von Frans Fuchs, 1922. 35 pp.

Heft 4.—Die Eisengewinnung von den ältesten Zeiten. Von M. Schwarz and F. D., 1925, 52 pp.

Heft 5.—Die Entwicklung der chemischen Grossindustrie. Von A. Zart, 1922, 48 pp.

Heft 9.—Die Entwicklung der Chemie zur Wissenschaft. Von W. Roth, 1922, 32 pp.

——— *Beiträge zur Geschichte der Naturwissenschaften und der Technik. Von E. O. von Lippmann.—*Berlin*, 1923, 8vo, 322 pp.

Mostly chemical. Alchemy, and Alchemists; Alcohol; Sugar industry; Das mittelalterliche Hausbuch; Liebig, etc.

——— *The development of the sciences. By E. W. Brown and others. Ed. L. L. Woodruff.—*New Haven*, 1923, 8vo, 342 pp. 28 pl. of portraits.

Mathematics; Physics; Chemistry; Astronomy; Geology; Biology.

——— A guide to the Anglo-Saxon and foreign Teutonic antiquities in the British Museum.—*London*, 1923, 8vo, 192 pp. 17 pl.

——— *The history and progress of metallurgical science. By Sir Robert Hadfield. An address to the Birmingham University Metallurgical Society, 1923, 2 pts., 8vo.

Includes sections on the scientists and engineers of Birmingham and Sheffield; on the development of science; on the Royal Society; etc.

——— *Makers of Science. Mathematics, Physics, Astronomy. By Ivor B. Hart. —*London*, 1923, 8vo, 320 pp.

——— Conférences scientifiques. Par A. Turpain.—*Paris, Gauthier-Villars*, 1924. 8vo. *In progress.*

2.—L'eclairage et le chauffage électrique. La naissance d'une lampe à incandescence. 74 pp.

3.—L'air liquide (esquisse de l'histoire de la liquéfaction des gaz). 70 pp.

4.—La presse à bras à la linotype et à l'électrotypographie. 108 pp.

5.—*Le cinematographie, son invention, etc.; le film coloré, le film parlant. 96 pp., 2 pl.

Popular lectures based on sound historical reading. Reviewed in La Nature, 27 Dec., 1924, p. 209.

——— A guide to the mediaeval antiquities and objects of later date [11th-18th centuries] in the British Museum.—*London*, 1924, 334 pp., 17 pl., 8vo.

——— *Handbook to the Exhibition of Pure Science, arranged by the Royal Society. British Empire Exhibition, Wembley, 1924, 228 pp.—*London*, 1924.

Includes notes on early scientific apparatus exhibited; Sir R. Glazebrook on the origins of wireless, etc.

General Works—*continued.*

——— *Pioneer inventions and pioneer patents. A lecture [at] Purdue University. By Frank Keiper. 2nd ed.—*Rochester, N.Y*, [1924], 8vo, pp. 156.

[First Edition in 1923].

Some of the principal inventions (steam engine, telegraph, rubber vulcanising, sewing machine, etc.) and patent litigation thereon.

——— *Popular research narratives. Collected by the Engineering Foundation. —*Baltimore, Williams & Wilkins*, 1924-5, 2 vols., portraits.

Popular accounts of modern inventions and discoveries based on information from the investigators themselves.

——— *Ruhmesblätter der Technik von den Urerfindungen bis zur Gegenwart. Von F. M. Feldhaus. 4te Aufl.—*Leipzig*, 1924, etc. *In progress.*

First Edition in 1910.

——— Taten der Technik. Ein Buch unserer Zeit. Hrsg. von Hanns Günther. —*Zürich, Verlag Rascher*, 1924, 8vo, 2 vols.

Popular. Well illustrated with photographs of old machines preserved in museums, portraits, etc. Reviewed in Genie Civil, Vol. 85, 1924, p. 536.

——— The treatise of Al-Jazarî on Automata. Leaves from a MS. of the Kitâb fî Ma'arifat al-Hiyal al Handasiya in the Museum of Fine Arts, Boston, and elsewhere. By A. K. Coomaraswamy. —*Boston*, 1924, 21 pp. 8 pl.

Early 13th Century work. Water clocks, blood-letting measuring instrument, water-raising apparatus, automata. Reviewed in Isis VII., 1924. p. 191.

——— *Le machinisme universel, ancien, moderne et contemporain. Par E. Pacoret.—*Paris*, 1925, 570 pp. 4 pl.

Pp. 536-64. Table synoptique et chronologique des inventions et découvertes depuis les temps les plus reculés à nos jours.

——— *Metallurgy and its influence on modern progress with a survey of education and research. By Sir Robert A. Hadfield.—*London*, 1925, 8vo, 404 pp. 54 pl.

Chapter on the birth of science; the rise of steam; the rise and importance of alloy steels; fuel economy; scientific societies. And a translation of Xavier de la Sante's poem "Ferrum," with notes.

——— *Science and scientists in the 19th century. By R. H. Murray. Introduction by Sir Oliver Lodge.—*London*, [1925], 8vo, 468 pp.

Jenner; Simpson; Helmholz; Joule; Darwin; Pasteur; Lister; Forgotten Scientists.

——— The Wonderful Century. By A. R. Wallace. New ed.—*London, Allen & Unwin*, 1925, 8vo, 539 pp.

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Adams, Henry (1846-)—*Some reminiscences. Seventy five years' work in civil engineering. By Henry Adams. Issued by the Institution of Structural Engineers.—*London*, 1925, 4to, 20 pp., portraits.

Aeronautics—*Due falsificazioni del settecento nella storia dell' aeronautica e dell' aviazione. Da Guiseppe Boffito. (Reprint from "Bibliofilia," Vol. 21).—*Firenze, Leo S. Olschki*, [1920], 4to, 24 pp.

Disputes the alleged crossing of the Channel in 1751 by Andrea Grimaldo, and the Passarola legend of Bartolomeo Lourenço [de Guzmao], 1709. Also describes the writing of Pier Jacopo Martelli relating to aviation.

——— *A history of aeronautics. By E. C. Vivian. With a section on progress in aeroplane design, by W. L. Marsh.—*London*, 1921, 8vo, 532 pp. 56 pl.

——— Les Vainqueurs de l'Air, Histoire des Aeronautiques. Par H. de la Vaulx.—*Paris, Hachette*, 1921.

——— *Aeronautics. Catalogue of the collections in the Science Museum. With supplement by M. J. B. Davy.—*London*, 1922-24, 2 pts., 8vo.

——— *L'aeronautique des origines à 1922. Par Comte Henry de La Vaulx and others.—*Paris*, 1922, fol., 44 pp., 106 pl.

——— L'evolution de l'aeronautique. Par Marcel Jauneaud.—*Paris, Flammarion*, 1923, 12mo, 284 pp.

Revd. in Rev. Gén. des sciences pures, etc., 1923, p. 408.

——— *Luftfahrten einst und jetzt. Von F. M. Feldhaus. 2te Aufl.—*Berlin*, 1923, 8vo, 132 pp., 15 pl., frontis.

——— *Aeronautical prints and drawings. By W. Lockwood Marsh.—*London*, 1924, 4to, 56 pp., 87 pl., frontis.

——— Entwicklung und gegenwärtige Stand des Metallflugzeugbaues. Von C. W. Erich Meyer.—*Dresden, Hellmet Dirscher*, 1924, 4to, 20 pp.

Reprint from Deutsche Motor Zeitschrift, 1924, No. 1 & 2. Second edition, 1925, 31 pp.

——— *The history of aeronautics in Great Britain from the earliest times to the latter half of the nineteenth century. By J. E. Hodgson.—*London*, 1924, 8vo, 458 pp., 90 pl., frontis.

——— *See also* AIRSHIPS; ARISTOTLE; BAUER, M.; PILATRE DE ROZIER.

Aeronautics: Gliding—*Gliding and soaring. A survey of man's endeavour to fly by natural methods. By J. B. Weiss.—*London*, 1923, 8vo, 184 pp., 8 pl.

Aeronautics: Italy—Il volo in Italia. Storia documentata e aneddotica dell' aeronautica e dell' aviazione in Italia.—*Firenze, Barbéra*, 1921, 12mo, 392 pp.

"A scholarly and comprehensive history."—J. E. Hodgson.

Agriculture: Egypt—Die Landwirtschaft im hellenistischen Aegypten. Von Michael Schnebel. Mit Beiträgen von Walter Otto und Franz Pluhatsch.—*München, C. H. Beck*, 1925, etc. [Bd. 1, Der Betrieb der Landwirtschaft, pp. 398]. *In progress.*

Reviewed in Archivio d. Storia della Scienza, VII., 1926, pp. 149-50.

——— L'agriculture dans l'ancienne Egypte. Par F. Hartmann.—*Paris, Librairies Imprimeries Réunies*, 1923, 332 pp.

Reviewed in Rev. Gen. des Sciences, June 15, 1924, p. 345.

Agriculture: England—A short history of English Agriculture and Rural Life. By C. J. Hall.—*London, Black*, 1924, 8vo, 160 pp., 8 pl.

——— *Old farming methods in East Yorkshire. By T. Sheppard. (Hull Museum Publication. Reprinted from the Official Handbook of the British Association at Hull, 1922).—*Hull*, 1923, 8vo, 16 pp.

Agriculture: United States — History of agriculture in the Northern United States, 1620-1860. By P. W. Bidwell and J. I. Falconer.—*Washington: Carnegie Institution*, 1925, pp. 524.

Reviewed in Nature, April 10, 1926, pp. 506-8.

Airships—*Funfundzwanzig Jahre Zeppelin-Luftschiffbau. Von L. Dürr.—*Berlin*, 1924, 4to, 88 pp., 1 pl., portr. frontis.

——— Daz Zeppelinluftschiff, seine Entwicklung. Tätigkeit und Leistungen. Von Franz Kollmann.—*Berlin, Krayn*, 1924, 8vo, 105 pp., 35 pl.

Reviewed in Zeits. f. Flugtechnik. XV., 1924, p. 275.

A.-B. Lindholmen Motala—*Minnesskrift med anledning av Motala Verkstads hundraariga verksamhet 1822-1922.—*Motala*, 1922, 4to, 326 pp.

Aktienbrauerei zum Löwenbräu in München—*Geschichte der Aktienbrauerei zum Löwenbräu in München, 1383-1921. Im Auftrag der Brauerei anlässlich ihres 50 jährigen Bestehens als Aktien-Gesellschaft, bearbeitet von Dr. Hermann Dihm.—*München*, 1922, fol., 64 pp., 8 pl.

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Alchemy—Alchemy: ancient and modern. By H. S. Redgrove. 2nd ed.—*London, Rider*, 1922, 161 pp., 16 pl.

Reviewed in Chemical News, April 7, 1922, p. 194. "Almost the only work on this subject in English, and certainly the best with which we are acquainted."

——— *See also* GEBER.

Alloys: Non-Ferrous—*Tutenag and paktong. With notes on other alloys in domestic use during the eighteenth century. By A. Bonnin.—*Oxford*, 1924, sm. 4to, 110 pp., 29 pl.

Alphabet—*See* WRITING.

Alum Industry—*Vierzig Jahre Geschichte der Firma Otto Kauffmann, Dresden-Medersedlitz.—*Berlin*, [192?], 4to.

Pp. 49-56. Zur Geschichte der Tonerde—Verbindungen insbesondere des Alauns und der schwefelsauren Tonerde. Von F. M. Feldhaus.

Aluminium—*Die Aluminium - Industrie. [Von F. Winteler]. In 2te Aufl. neu bearb. von Rudolf Debar.—*Braunschweig*, 1925, 8vo. 344 pp.

Pp. 1-40. Geschichte des Aluminiums.

Ampère, André Marie (1775-1836)—*A la mémoire de André-Marie Ampère. Special number of "Revue General de l'Electricité."—*Paris*, 1922, 4to, 306 pp. portr.

Archimedes of Syracuse (B.C. 287-212)—Oeuvres complètes d' Archimedes. Traduites du grec en français, avec une introduction et des notes, par P. Ver Eecke.—*Paris, Desclée*, 1921, 612 pp.

Long introduction on the life and work of Archimedes. Reviewed in Isis, IV., 1922, p. 499-500.

——— *Der Tod des Archimedes. Von Franz Winter. Zweiundachtzigstes Winckelmannsprogramm der Archaologischen Gesellschaft zu Berlin.—*Berlin*, 1924, 4to, 24 pp., 2 pl.

Discussion of a Herculaneum mosaic depicting the death of Archimedes at the hands of a Roman soldier. The design agrees with the well-known tradition except that Archimedes is drawing at a small table instead of on the ground.

Aristarchus of Samos (3rd Cent. B.C.)—The Copernicus of Antiquity. By Sir Thomas Heath.—*London, S.P.C.K.*, 1921, 8vo, 62 pp. (*Pioneers of Progress*).

Aristotle—*Aristotile Aeronauta. Da Guiseppe Boffito (Reprint from Bibliofilia, Vol. 22).—*Firenze, Leo S. Olschki*, 1921, 4to, 7 pp.

Discusses the contributions of A. to the science of aerial navigation.

Arkwright, Sir Richard (1732-1792)—*R.A. By J. H. Crabtree.—*London*, 1923, 8vo, 80 pp., portr.

Arms and Armour—A record of European armour and arms through seven centuries. By Sir G. F. Laking. With an introduction by the Baron de Cosson.—*London, Bell*, 1920-22, 5 vols.

——— Armour and weapons in the Middle Ages. By C. H. Ashdown.—*London, Harrap*, 1925, 8vo, 220 pp.

——— *See also* FIREARMS.

Artificial Limbs—*Artificial limbs and amputation stumps. By E. M. Little.—*London*, 1922, 8vo, 328 pp., 19 pl.

Pp. 1-21, historical.

Assyria: *See* CHEMISTRY: ASSYRIAN.

Astrolabe—Zur Geschichte des Astrolabs. Von Josef Frank.—*Erlangen*, 1920, 33 pp.

An extract from a larger work not yet issued.

——— *Die Verwendung des Astrolabs nach al Chwârizmî. Von J. Frank. (*Abhandlungen zur Geschichte der Naturwissenschaften, &c., Heft* 3).—*Erlangen*, 1922, 8vo, 32 pp.

——— Ein Astrolab aus dem indischen Mogul-reiche. Von Josef Frank und M. Meyerhof. — *Heidelberg, Winter*, 1925, 48 pp.

Astronomical Instruments—Le plus vieil instrument européen d'astronomie nautique (IIIe siècle). Par Jean Mascart. Pamphlet, 8vo, 1923.

This instrument part of the Antikythera treasure now in the National Museum at Athens and ascribed to the 3rd century A.D. is believed by the author to be a form of astrolabe, but sufficient is not preserved to give any definite opinion.—H.W.D.

——— See also ASTROLABE.

Astronomy—Histoire de l'astronomie. Par F. Boquet.—*Paris, Payot*, 1925, 8vo, 509 pp.

Reviewed in Archivio di Storia della Scienza, VII., 1926, pp. 125-6.

——— Histoire de l'astronomie. Par E. Doublet.—*Paris, Gastoin Doin*, 1925.

Reviewed in L'Horloger, Jan., 1926, p. 399.

——— Scritti sulla storia della astronomia. Da Giovanni Schiaparelli.—*Bologna, Zanichelli*, 1925 etc. *In progress.*

Reprints with corrections of S.'s works. Vol. 1 deals with the Astronomy of the East, including that of the Old Testament and of the Greeks. Reviewed in Jl. British Astronomical Assoc., Feb., 1926, p. 160.

——— *See also* ROYAL ASTRONOMICAL SOCIETY.

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Automobiles—*Land Transport. II. Mechanical road vehicles. Catalogue of the collections in the Science Museum, South Kensington. With descriptions and historical notes and illustrations. Compiled by E. A. Forward.—*London*, 1925, 8vo, 88 pp., 5 pl.

——— *See also*, BENZ, C.; FORD, H.; TRANSPORTATION, AUTOMOBILE

Bacon, Roger (1214-1294)—*R. B., the father of experimental science and mediæval occultism. By H. S. Redgrove.—*London*, 1920, 8vo, 64 pp.

Badische Anilin- und Soda-Fabrik—*[History and description of the firm and its activities]. — [*Ludwigshafen - a - Rh.*, 1925]. 4to, 238 pp.

Bakelite—*The story of bakelite. By J. K. Mumford.—*New York* [1924], 8vo, 80 pp., frontis.

Baldwin Locomotive Works, *Philadelphia*—*History of the Baldwin Locomotive Works, 1831-1924. [1924], 8vo.
*Previous volume, 1831-1898, issued in 1897.

Bauer, Melchoir (1733- ?)—*Die Flugzeug-Handschrift des Melchior Bauer von 1764. (Faksimile-Drucke des Thüringer Staats-Archiv).—*Rudolstadt*, 1924, fol., 8 ll., facs. MS.
Describes a flying machine designed by M. B. A model has been made from the description and is now in the museum at Greiz. In 1763 Bauer came to London to obtain assistance from George III., but without success.

Bavaria—*1815-1915. Hundert Jahre technische Erfindungen und Schöpfungen in Bayern.—*München*, 1922, 4to, 370 pp.

Bedwarmers—*See* FOOTWARMERS.

Benz, Carl (1844—).—*C. B. Lebensfahrt eines deutschen Erfinders. Erinnerungen eines Achtzigjährigen. — *Leipzig*, 1925, 8vo, 160 pp., portr.

Biography—*Gli scienziati italiani dall' inizio del medio evo ai nostri giorni. Repertorio biobibliografico. Da Aldo Mieli. Vol. 1, etc.—*Roma*, 1921, etc. *In progress.*

——— *Biographical notices of the John Fritz Medallists.—[*New York*, 1922], 8vo, 127 pp. 18 pl. portraits.
The medal is presented for achievement in applied science. Among the recipients have been Kelvin, Westinghouse, Graham Bell, Edison, Alfred Noble, Sir Wm. White, Orville Wright, and Sir Robert Hadfield.

——— Buch berühmter Ingenieure. Grosse Männer der Technik, ihr Lebensgang und ihr Lebenswerk. [Neue Aufl.]. Von Richard Hennig.—*Berlin, Neufeld & Henius*, 1923, 8vo, 256 pp., 15 pl.
Nobel, Bessemer, John Fowler, Riggenbach, Intze, Eyth, the brothers Wright, Diesel, Goethals, Marconi. First ed., 1911.

Biography—*continued.*

——— Führende Männer. Von Heinrich Wiesenthal. Bd. 4. Ingenieure.—*Leipzig*, 1924, 64 pp.
Short biographies of Watt, W. v. Siemens, Riggenbach, Bessemer, C. v. Bach, Taylor.

——— Masters of science and invention. By Floyd L. Darrow.—*London, Chapman & Hall*, 1924, 8vo, 356 pp., 24 pl.
A popular story of science in biographical form. Many portraits. Reviewed in Science Progress, XIX., p. 537-8.

——— *Männer der Technik. Ein biographisches Handbuch. Hrsg. im Auftrage des Vereins deutscher Ingenieure von Conrad Matschoss.—*Berlin*, 1925, 4to, 315 pp.
Short biographies, with several pen portraits, in alphabetical order.

——— ——— Offener Brief an Herrn Dr.-Ing. Chr. Conrad Matschoss . . . über sein Buch "Männer der Technik." Von F. M. Feldhaus.—*Berlin*, 1925, 8vo, 24 pp.

See also under subjects and under separate names for individual biographies.

Biography, Local: Dundee—*James Bowman Lindsay [electric light, telegraph, etc.] and other pioneers of invention [George Lowdon, George Worrall, and David Justice]. By A. H. Millar. With a foreword by G. Marconi.—*Dundee*, 1925, 8vo, 96 pp., 4 pl.

Bleaching—*A history of bleaching. By S. H. Higgins.—*London*, 1924, 8vo, 184 pp., 7 pl., frontis.

Bookbinding—*See* PRINTING.

Boot and Shoe Industry: United States—The organisation of the boot and shoe industry in Massachusetts before 1875. By B. E. Hazard.—*Cambridge, Mass., Harvard U. P.*, 1922.
Reviewed in Management Engineering, June, 1922, p. 386.

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——— Gli studi intorno a Leonardo da Vinci nell' ultimo cinquantennio (1872-1922). Da Ettore Verga.—*Roma, Maglione e Strini*, 1923, 160 pp.
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A chronology of invention, discovery, and practice, B.C. 1500—A.D. 1924.

——— Wireless of to-day: describing the growth of wireless telegraphy and telephony, etc. By C. R. Gibson and W. B. Cole.—*London, Seeley*, 1924, 8vo, 318 pp., 16 pl.

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Report of the Council for the Session, 1924-1925

Presented at the Annual General Meeting, Nov. 18th, 1925.

The Council has pleasure in submitting the Annual Report for the Session 1924-25. The period has been one of steady growth and broadening out in more than one direction.

Thirty-six new members—one of whom is a woman—have been elected during the year. Five Libraries and Institutions have subscribed for the *Transactions*. Four members have resigned for various reasons and four names have been removed from the Roll of Membership. The Council records with regret the death of Mr. William Munro and Mr. A. Seymour Jones, C.B.E.; the latter contributed a paper to the first volume of the *Transactions*.

The large proportion of members in the North American continent has been more than maintained; there has been an increase of eighteen and of one Institution, making a total of 49. In view of the large membership in America it has been considered desirable to arrange for the control of the interests of the Society there. This need has been met by the appointment of a Honorary Corresponding Secretary in New York, Mr. C. E. Davies having been good enough to accept the office. The net increase in Membership has been therefore thirty-one and the position of the Society is that there are 191 Members and 35 Institutions on the Roll.

During the Session, eight meetings have been held, six in London, one by the American members in New York, and one at Gloucester, the latter being the summer meeting.

The papers presented were as follows:—

"Notes on Coalbrookdale and the Darbys." John A. Hall, M.Inst.C.E., Member, October 8.

"The Discoveries of the Darbys of Coalbrookdale." Thomas S. Ashton, M.A. October 8.

"Some Original Models of Smeaton's Eddystone Lighthouse." Thomas Rowatt, M.I.Mech.E., Member, November 12.

"Development of the Cylinder Boring Mill." E. A. Forward, A.R.C.S., M.I.Mech.E., Treasurer, December 17.

"Windmills of Cape Cod." E. P. Hamilton, Member, January 28.

"Lighting by Coal Gas in 1760." J. Macfarlan, Member, January 28.

"John Patison of Airdrie." David Brownlie, B.Sc., Member, January 28.

"Gun-Making Handicrafts." C. E. Greener, Member of Council, March 4.

"Glass found in Egypt." Sir Flinders Petrie, F.R.S. April 21.

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"Chiddingfold Glass and its Makers in the Middle Ages." Mrs. Brenda Halahan, April 21.

"Notes on the Records of the Trade Guilds of Gloucester." Roland Austin. June 18.

It is again a source of satisfaction to the Council that one of the papers was contributed by an American member; indeed it was read both in London and in New York. The meeting at the latter city was held at the Engineers' Club and was preceded by a dinner; the proceedings were enthusiastic and lasted to a late hour. A cabled greeting was sent to the meeting in London as follows:—

Hearty greetings from first American Meeting Newcomen Society, Penrose, to which the reply was sent:—

Council Newcomen Society send greetings and applaud first steps of sturdy infant.

Besides listening to the paper by Mr. E. P. Hamilton on "Windmills of Cape Cod,"[1] much discussion took place on the best means of carrying on and expanding the work of the Society in America; the fruit of this it is hoped will be seen later.

As in previous sessions on several evenings more than one paper was presented. On one evening also a loan exhibit of quite a number of objects of interest was brought together.[2] This procedure appeared to meet with approval.

At the Annual General Meeting an alteration was made in Rule IV. to include in the Council as a separate class those who had passed the Presidential Chair.

The Summer Meeting lasted three days—June 18th to 20th—the headquarters being at Gloucester. The first day was devoted to the Forest of Dean, the second to the Stroud Valley and the Cotswolds, while the third was spent in Gloucester itself.[3]

On August 5th, a chaplet which the Society forwarded to the Mayor of Dartmouth, Dr. H. J. Campbell, was placed by him in the presence of members of the Town Council, and of visitors, on the monument to Newcomen in the Town Gardens. The chaplet bore the inscription: "In homage to Thomas Newcomen, died August 5th, 1729, from the Newcomen Society for the Study of the History of Engineering and Technology."

On the anniversary of the death of James Watt, August 19, a laurel wreath was placed on his bust in the Science Museum at South Kensington, to mark in a slight way the gift to the nation by Major J. M. Gibson Watt of Watt's Workshop from Heathfield.

As an outcome of the November meeting it was decided to send to Mr. Orville Wright a letter of congratulation on the coming of age on December 17th of the

[1] *See* p. 39.
[2] *See* p. 56.
[3] *See p.* 86 for full report.

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aeroplane and the great share that he and his brother had in bringing about the conquest of the air.

The Hon. Secretary has received a number of requests for historical information and in most cases it has been possible to send satisfactory replies, sometimes resulting in an addition to the membership.

The statement of accounts and balance sheet, submitted by the Honorary Treasurer, shows that the financial affairs of the Society are in a satisfactory condition. It is to be noted, however, that from the balance in hand must be deducted the cost of printing *Transactions*, Vol. IV., which cost would have appeared in this year's accounts but for the delay that has taken place in the production of the volume.

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THE NEWCOMEN SOCIETY.

Revenue Account from 1st October , 1924, to 30th September, 1925.

Dr. EXPENDITURE.

	£	s.	d.	£	s.	d.
To Hire of Rooms and Expenses of Ordinary Meetings	11	14	6			
,, Summer Meetings	33	3	6			
,, Printing and Stationery, including preparation of Transactions	184	6	10½			
,, Typing and Mimeographing and Clerical Assistance	21	13	6			
,, Postage, Telegrams, Parcels, Stamps, and Travelling Expenses	13	14	7½			
,, Bank Charges and Commission		4	5			
				265	0	5
,, Excess of Income over Expenditure				62	5	6
				£327	5	11

(Signed) A. M. BUSHELL, *Hon. Auditor.*

INCOME. Cr.

	£	s.	d.	£	s.	d.
By Subscriptions and Donations for the year	210	9	7			
,, Members' and Visitors' Contributions to Summer Meeting	35	0	3			
,, Sale of Transactions and Binding	75	2	3			
,, Bank Interest for the year	6	13	10			
				327	5	11
				£327	5	11

(Signed) E. A. FORWARD, *Treasurer.*

Balance Sheet as at September 30th, 1925.

LIABILITIES.

	£	s.	d.	£	s.	d.
Balance brought forward from October 1st, 1924	312	4	10½			
Surplus from Revenue Account, year ending September 30th, 1925	62	5	6			
				374	10	4½
				£374	10	4½

The above accounts have been examined with the Books and Vouchers, and found correct.

(Signed) A. M. BUSHELL, *Hon. Auditor.*

16th November, 1925.

ASSETS.

	£	s.	d.	£	s.	d.
Cash as under :—						
On deposit at Bank	320	0	0			
On current account	53	2	10			
In Treasurer's hands	1	7	6½			
				374	10	4½
Stock of " Transactions " not valued						
				£374	10	4½

(Signed) E. A. FORWARD, *Treasurer.*

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Obituary.

Alfred Seymour Jones.

Alfred Seymour Jones, C.B.E. (b. September 3, 1862, d. June 22, 1925), was the son of John Meredith Jones, of the Cambrian Leather Works—a firm which specialized in the manufacture from Welsh sheep skins of " roller leather " for cotton spinning. After passing through his father's works, Jones went to America to gain experience in tanneries and cotton mills there. After an absence of several years he returned to take part in the management of the Wrexham Tannery—travelling in all parts of the world where there was a prospect of forwarding the firm's interests. He thus obtained a world-wide experience as a practical tanner and he coupled with this scientific knowledge especially as regards the micro-structure of skins. His work on *The Sheep and its Skin* is a standard book on the subject. He was a man of considerable inventive capacity—especially in the domain of leather-working machines.

It is, however, in connection with the early history of spinning that Jones came into contact with our Society,[1] of which he was an original member. His friendship with members of the Arkwright family led to him to project a " Life of Sir Richard Arkwright," which still remains in MS., a duplicate being deposited in the Library of the Patent Office. From Arkwright he was led to an appreciation of the place of Da Vinci in the history of the spinning machine. History, however, was not his strong point. Jones was essentially a projector and man of action. In him exceptional mental capacity was combined with a splendid physique transmitted to him from his Cornish ancestors. Yet with all his strength of will, mind and body he was a singularly gentle and loveable man. Success in life left his simple habits of living unchanged. Of his many friends none will mourn his loss more sincerely than the present writer. E.W.H.

[1] *Transactions*, I., 50.

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The Newcomen Society

For the Study of the History of Engineering and Technology

LIST OF MEMBERS.

JANUARY, 1926.

† Indicates Contributor to Transactions.

Abbott, W. L., M.Am.S.M.E., Commonwealth Edison Co., 72, West Adams Street, Chicago, Ill.

Achard, F., 13, Avenue Mozart, Paris, XVIe.

Adamson, Daniel, M.I.Mech.E., P.O. Box 4, Hyde, Cheshire.

Ahrons, Ernest L., M.I.Mech.E., M.I.Loco.E., 16, Corporation Oaks, Nottingham.

Armstrong College, Newcastle-on-Tyne.

Arthur, A. E., 7, Sellars Avenue, Harlesden, N.W.10.

Ashberry, Miss A., A.M.S.E., Atalanta Ltd., 1-3, Brixton Road, S.W.9.

Bacon, Frederic, M.A., M.I.Mech.E., M.I.E.E., University College, Engineering Dept., Singleton Park, Swansea.

Bailey, R. M., The Old Town Cottage, Stratford-on-Avon.

Baker, Professor P. M., M.I.E.E., 88, Grove Park Terrace, Chiswick, W.4.

Barraclough, Lt.-Col. Sir Henry, K.B.E., B.E. (Sydney), M.M.E. (Cornell), M.Inst.C.E., University of Sydney, New South Wales.

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Beaumont, W. Worby, M.Inst.C.E., M.I.Mech.E., 20, Essex Street, W.C.2.

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Beggs, Professor George, Dept. of Civil Engineering, Princeton University, N.J., U.S.A.

Belaiew, Colonel N. T., O.B.E., 33, Elvaston Place, Queen's Gate, S.W.7.

Bell, A. R., Locomotive Publishing Co., 3, Amen Corner, E.C.4.

Bell, Sir Hugh, Bart, C.B., D.C.L., LL.D., Rounton Grange, Northallerton, Yorks.

Bennett, A. R., M.I.E.E., M.I.Loco.E., " Clifton," St. Peter Port, Guernsey.

Bibliothèque Nationale, Paris (Agent C. Klincksieck, 11, rue de Lille, Paris, VIIe).

Bigelow, Carle M., Park Square Buildings, Boston, Mass., U.S.A.

Bird, G. F., 27, Holwood Road, Bromley, Kent.

Birmingham Public Libraries (Reference Department), Ratcliff Place, Birmingham.

Blyth, Herbert, M.Inst.C.E., 32, Hampton Park, Clifton, Bristol.

Bodleian Library, Oxford.

Bolton, Lyndon, M.A., 4, Shakespeare Road, Bedford.

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Brady, H. W., M.I.MechE., M.I.E. (Ind.), Chief Inspector of Factories, The Secretariat, Ranchi, India.

Bridgeport Public Library, Bridgeport, Conn., U.S.A.

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California Institute of Technology, Pasadena, California, U.S.A. (per Prof. E. C. Watson).

Cambridge University Library, Cambridge.

Carpenter, H.V., M.Am.Soc., M.E., F.A.I.E.E., Dean of Engineering, State College of Washington, Pullman, Washington.

Chope, R. P., B.A., J.P., Fosfelle, Hartland, N. Devon.

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Cosgrave, J. Cotter, 3, St. Mary's Square, Paddington, W.2.

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Craver, Harrison W., Director, Engineering Societies Library, 29, West 39th Street, New York, U.S.A.

Crawford, Ivan C., Dean of Engineering, University of Idaho, Moscow, Idaho, U.S.A.

Crowther, J. G., Oxford University Press, Falcon Square, E.C.1.

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Sunniside 1763 12.

Esteemed Friend/

"Thy very Acceptable favour of the 9th ult claimd my earliest acknowledgments, which I Should immediatly have made, had not thy kind condescension in taking notice of my late honourd Husband: and requesting to be informd of any Circumstance which may be interesting relating him. Caused my delay - to recollect what might occur concerning his transactions or improvements in the Manufactory of Iron - So beneficial to this Nation but before I proceed further I cannot help commenting with thee in thy just observation, "that it has been universally Observed, that the Destroyers of mankind are recorded and remembered, while the Benefactors are unnoticed and forgotten" this Seems owing to the depravity of the mind, which Centres in reaping the present advantages and Suffering Obscurity to Vail the Original Causes of Such benefits, and even the very Names of those to whom we are indebted for the important discoveries, to Sink into Oblivion Whereas if they were handed down to posterity, gratitude would naturally arise in the Commemoration of their ingenuity, and the great advantages injoyed from their indefatigable Labours — I now make free to communicate what I have heard my Husband Say, and what arises from my own Knowledge, also what I am informd from a person now living, whose Father came here as a workman at the first beginning of this Pit Coal works

Then to begin at the Original. It was my Husbands Father, whose name he bore (Abraham Darby, who was the first that set on foot the Brass work at or near Bristol) that attempted to mould and cast Iron pots &c in Sand instead of Loam, (as they were wont to do, which made it a tedious & more expensive process) in which he Succeeded this first attempt was tryed at an old Furnace in Bristol. - about the year 1709 he came into Shropshere to Coalbrookdale and with other partners took a lease of the works, which only consisted of an Old Blast Furnace and some Forges he here cast Iron Goods in Sand out of the Blast Furnace that blowd with Good charcoal, for it was not yet thought of to blow with Pit Coal Sometime after he Suggested the thought, that it might be practable to Smelt the Iron from the ore in the Blast Furnace with Pit Coal upon this he first tryd with raw coal as it came out of the Mines, but it did not answer. he not discouraged he had the Coal Coakd into Cynder, as is done for drying Malt. and it then Succeeded to his Satisfaction But he found that only one Sort of pit Coal would Suit best for the purpose of making good Iron — These were beneficial discover

PAGE OF HOLOGRAPH LETTER, ABIAH DARBY TO A FRIEND, 1763.

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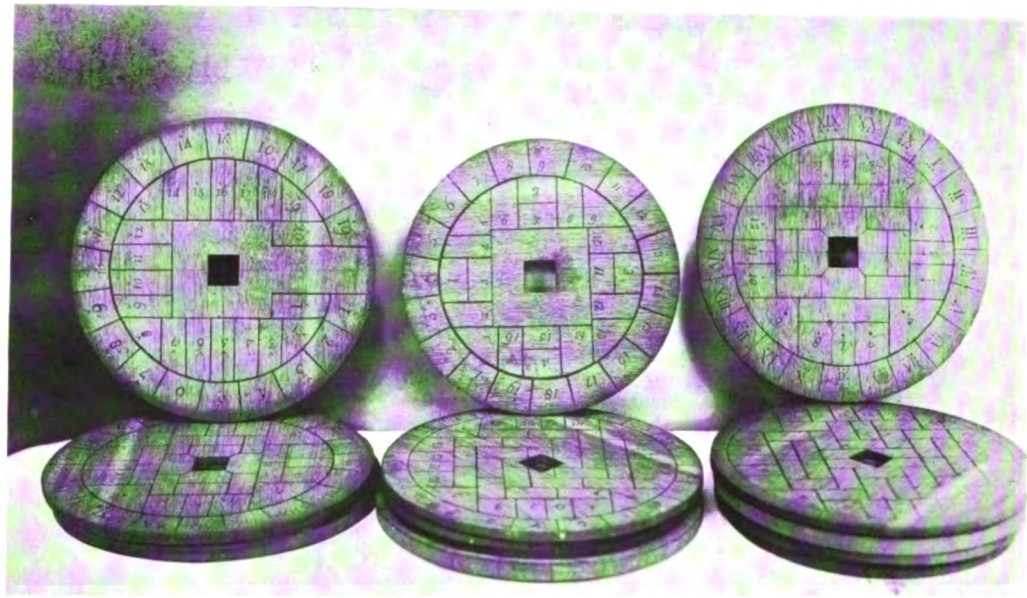

"DRAUGHTS" MADE BY RUDYERD FOR BUILDING HIS LIGHTHOUSE, 1706.

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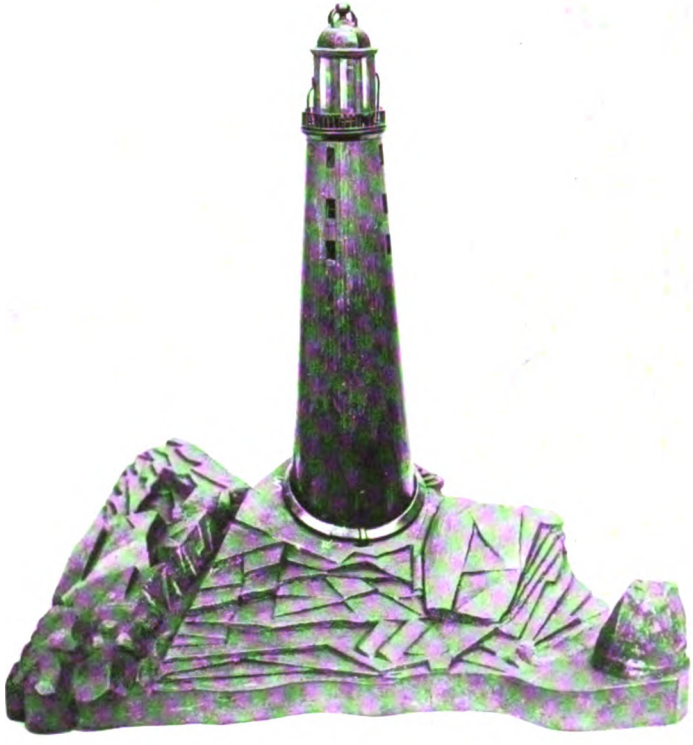
PLATE III.



MODEL OF RUDYERD'S LIGHTHOUSE, 1708-1755.

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MODEL OF SMEATON'S LIGHTHOUSE, 1759-1882.

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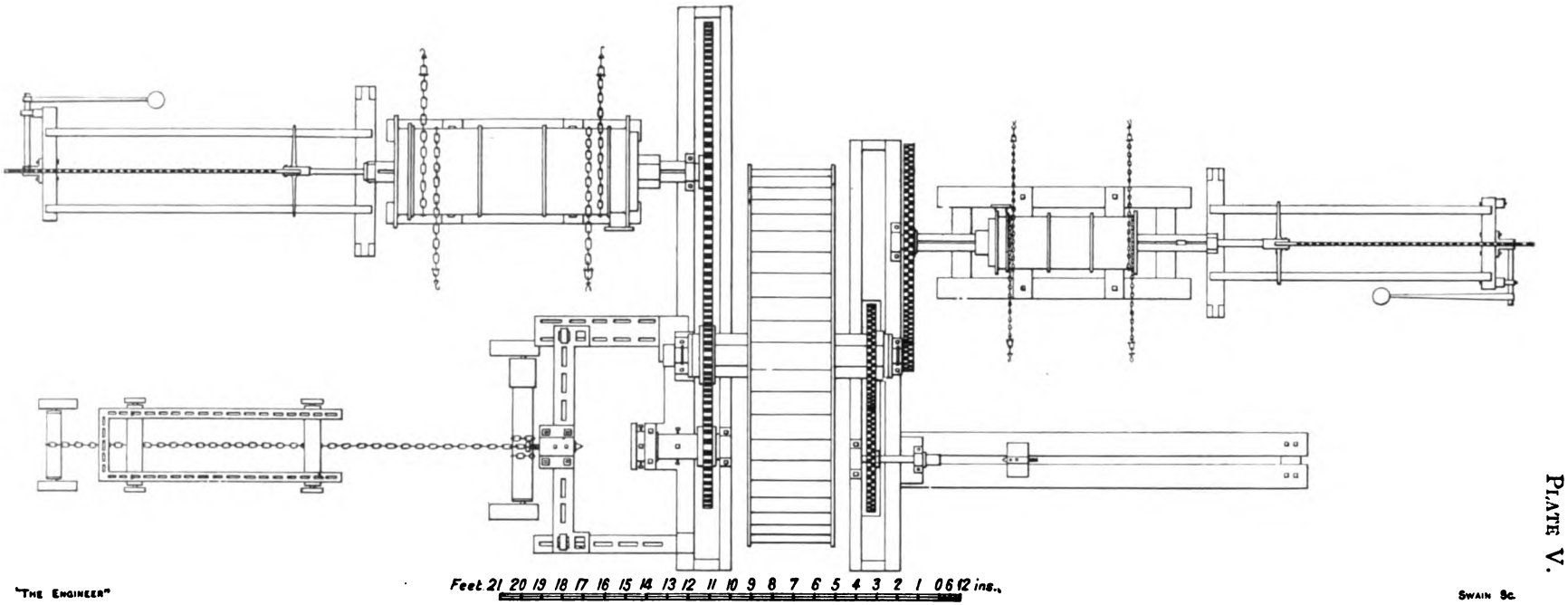
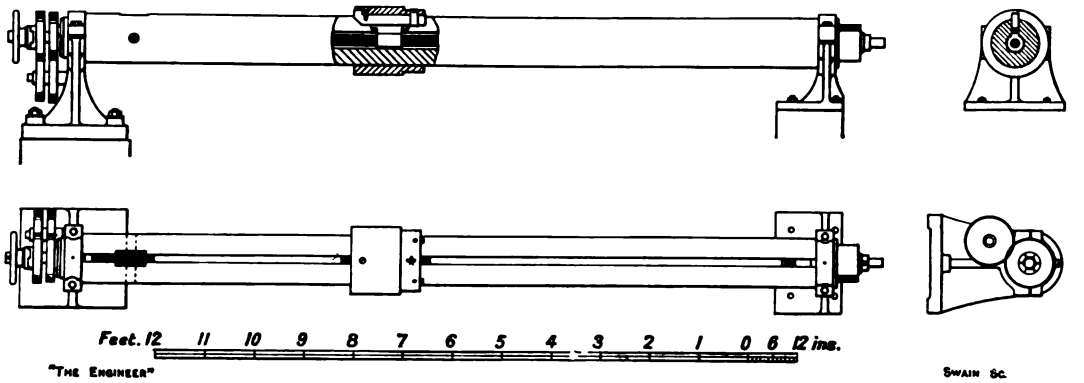


BERSHAM BORING MILL, 1775



BERSHAM BORING BAR IN THE SCIENCE MUSEUM.

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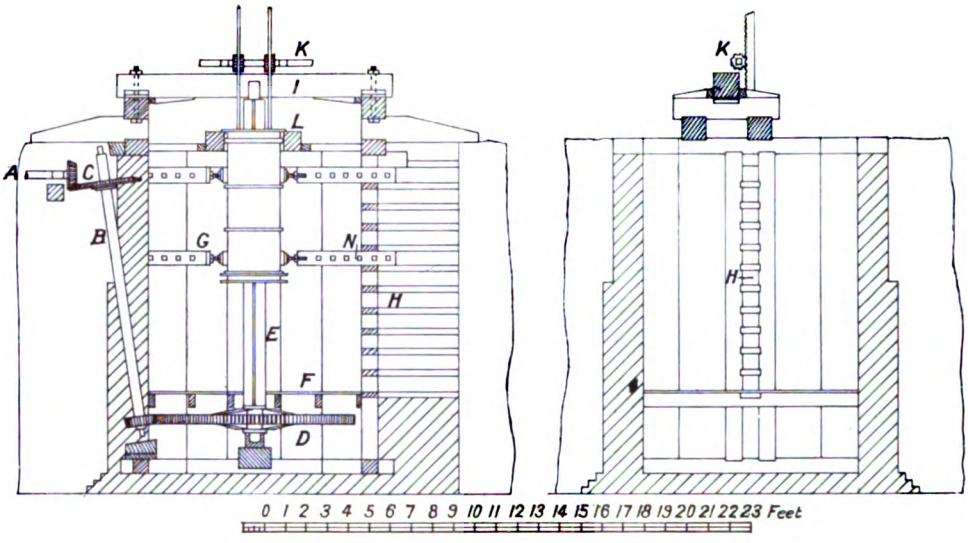
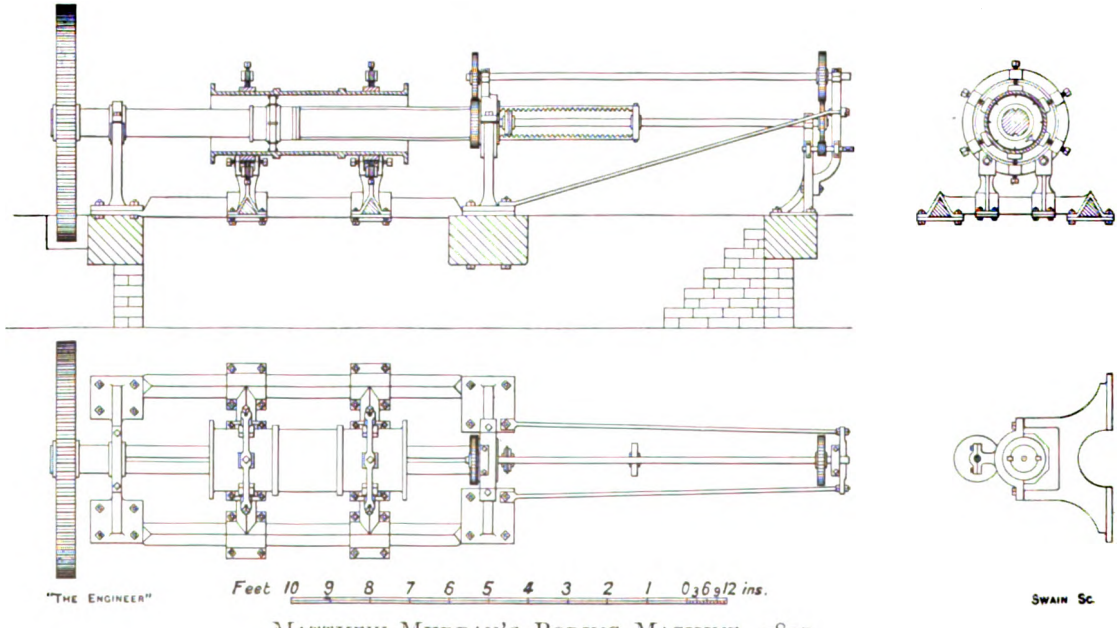


PETER EWART'S BORING MILL FOR SOHO FOUNDRY, 1795.



MATTHEW MURRAY'S BORING MACHINE, 1817.

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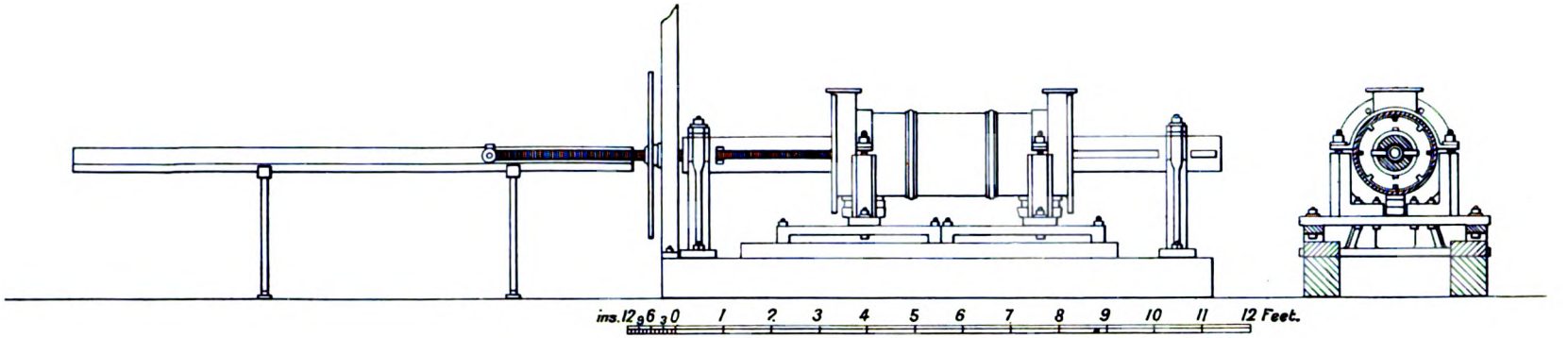
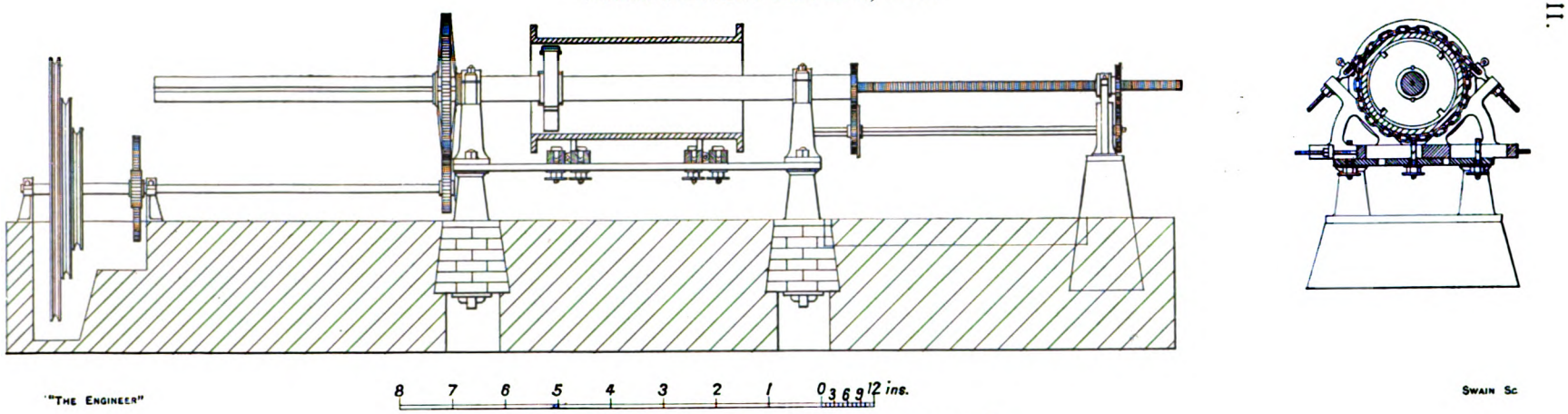


Dixon's Boring Machine, 1818.



Murray's Boring Machine at Chaillot, 1822.

Plate VII.

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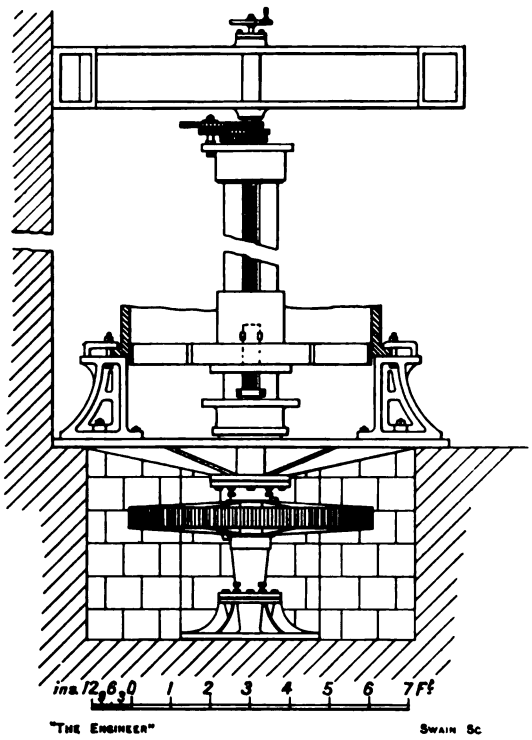

NASMYTH AND GASKELL'S BORING MACHINE, 1841.

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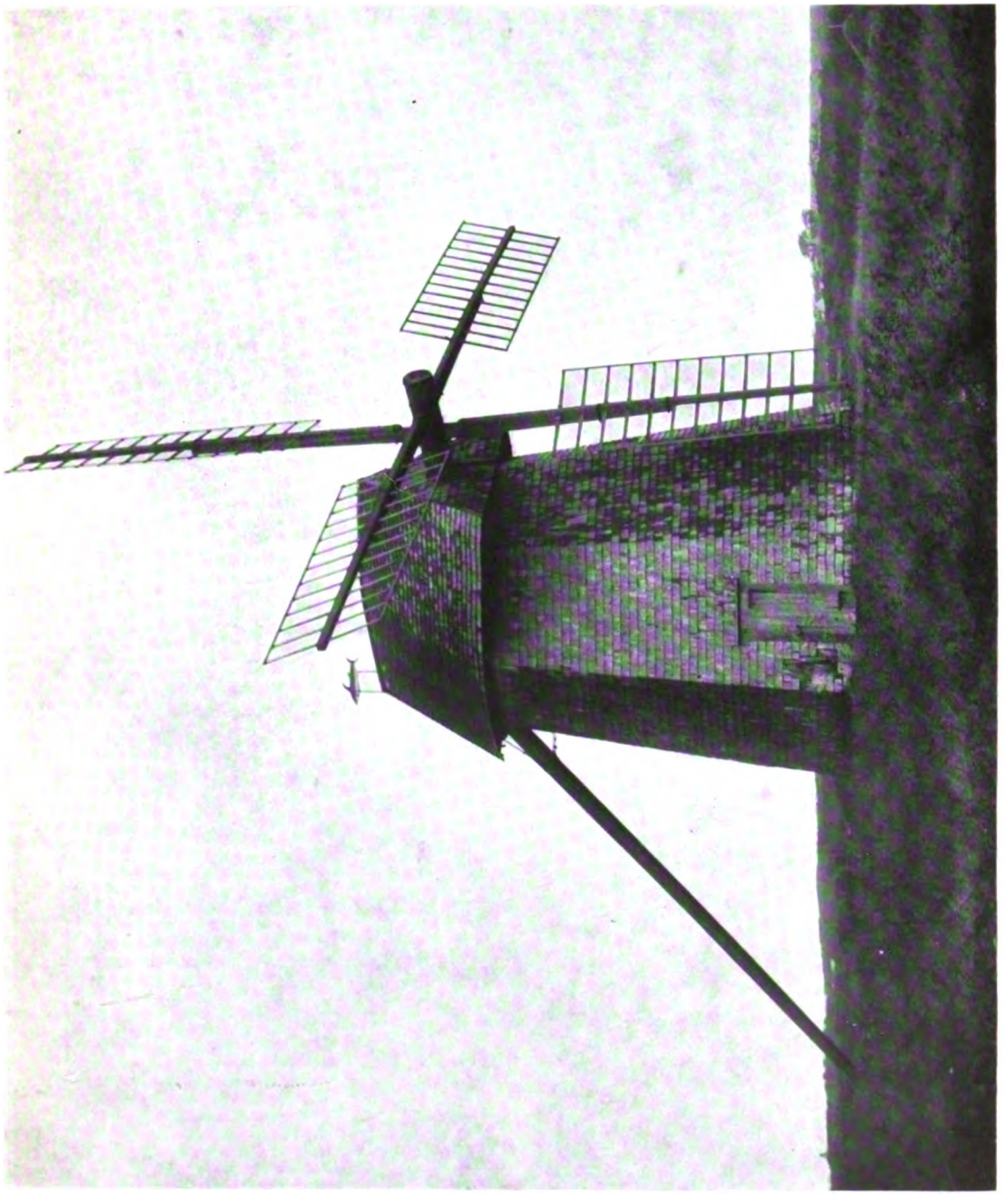
PLATE IX.



WINDMILL AT CHATHAM, MASSACHUSETTS, 1797, PRESENT DAY.

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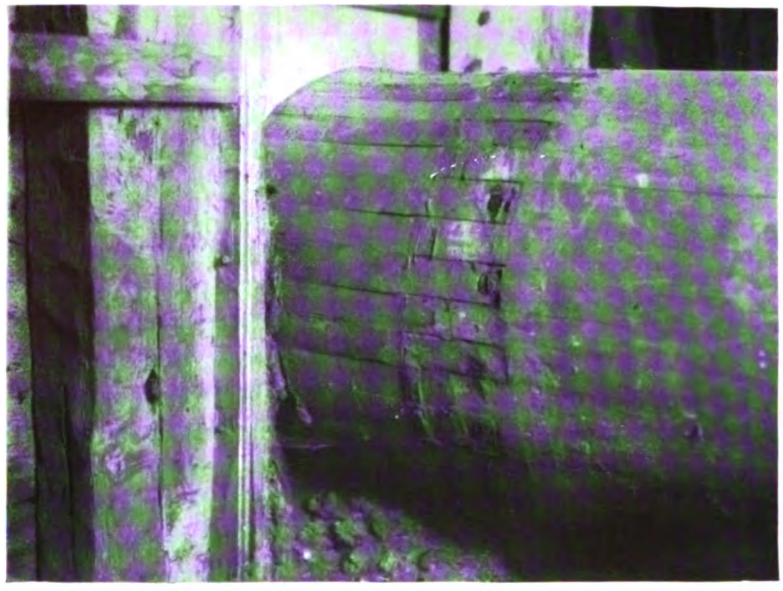
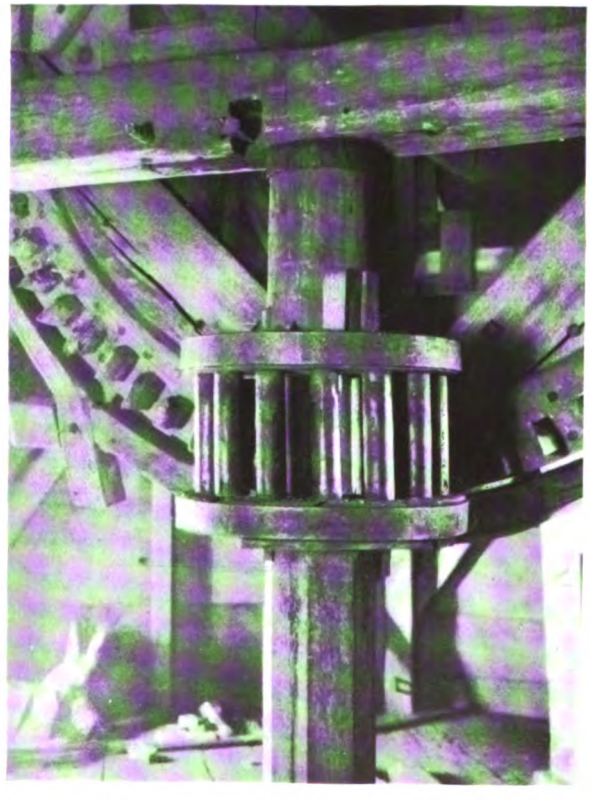


FRONT BEARING OF WINDSHAFT, CHATHAM WINDMILL, 1797.



BRAKE WHEEL AND TRUNDLE, SOUTH YARMOUTH WINDMILL, 1797.

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PLATE XI.

JOHN JAMES PATISON. 1828-1905.

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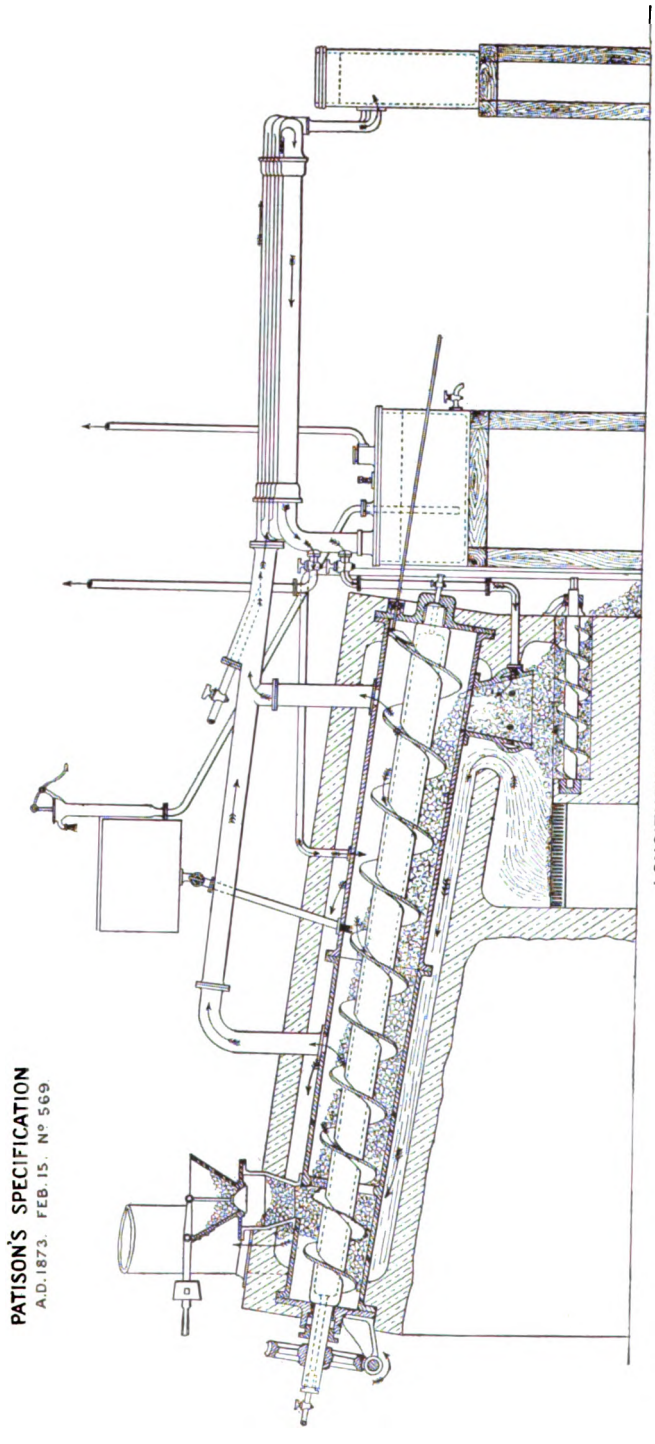
PLATE XII.



PATISON'S SCREW CONVEYOR RETORT FOR SHALE, 1873.

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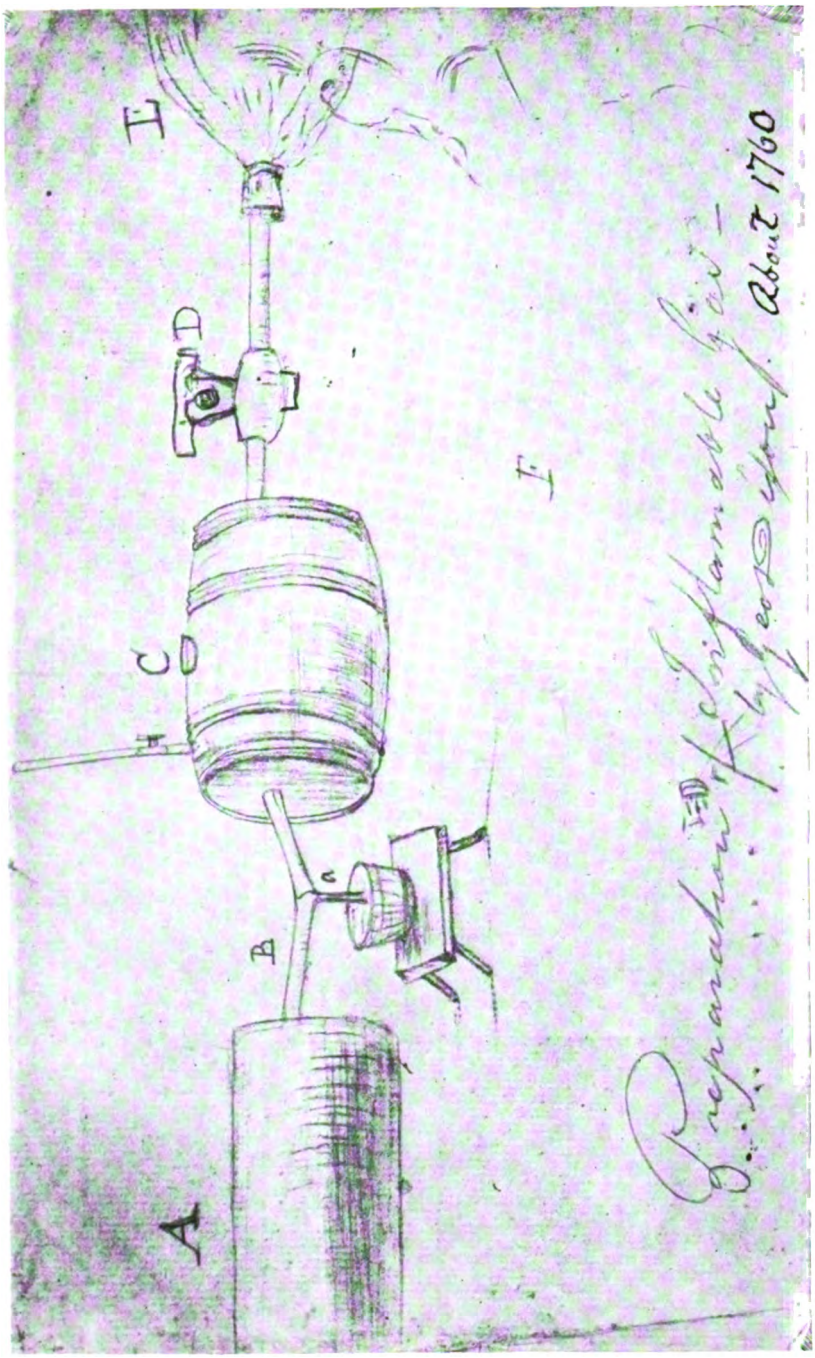

DIXON'S APPARATUS FOR MAKING COAL GAS, *c.* 1760.

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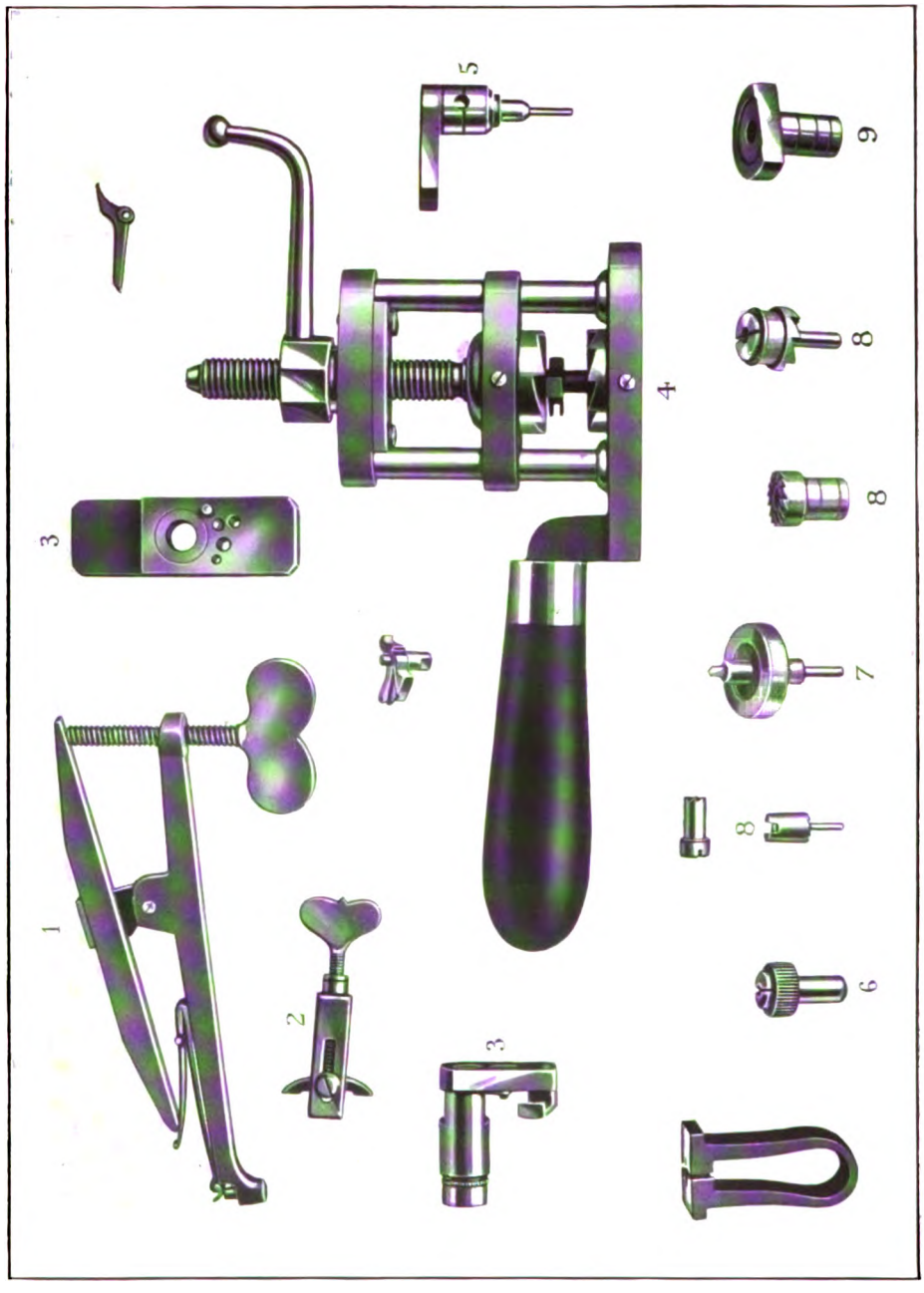
PLATE XIV.



GUN LOCK FILERS' TOOLS.

1, 2. Spring Cramps. 3. Swivel Plates. 4. Stocks with Die.
5. Peg Grinder. 6. Wheeler. 7. Pivot Bush,
8, 8, 8. Levellers. 9. Oval,

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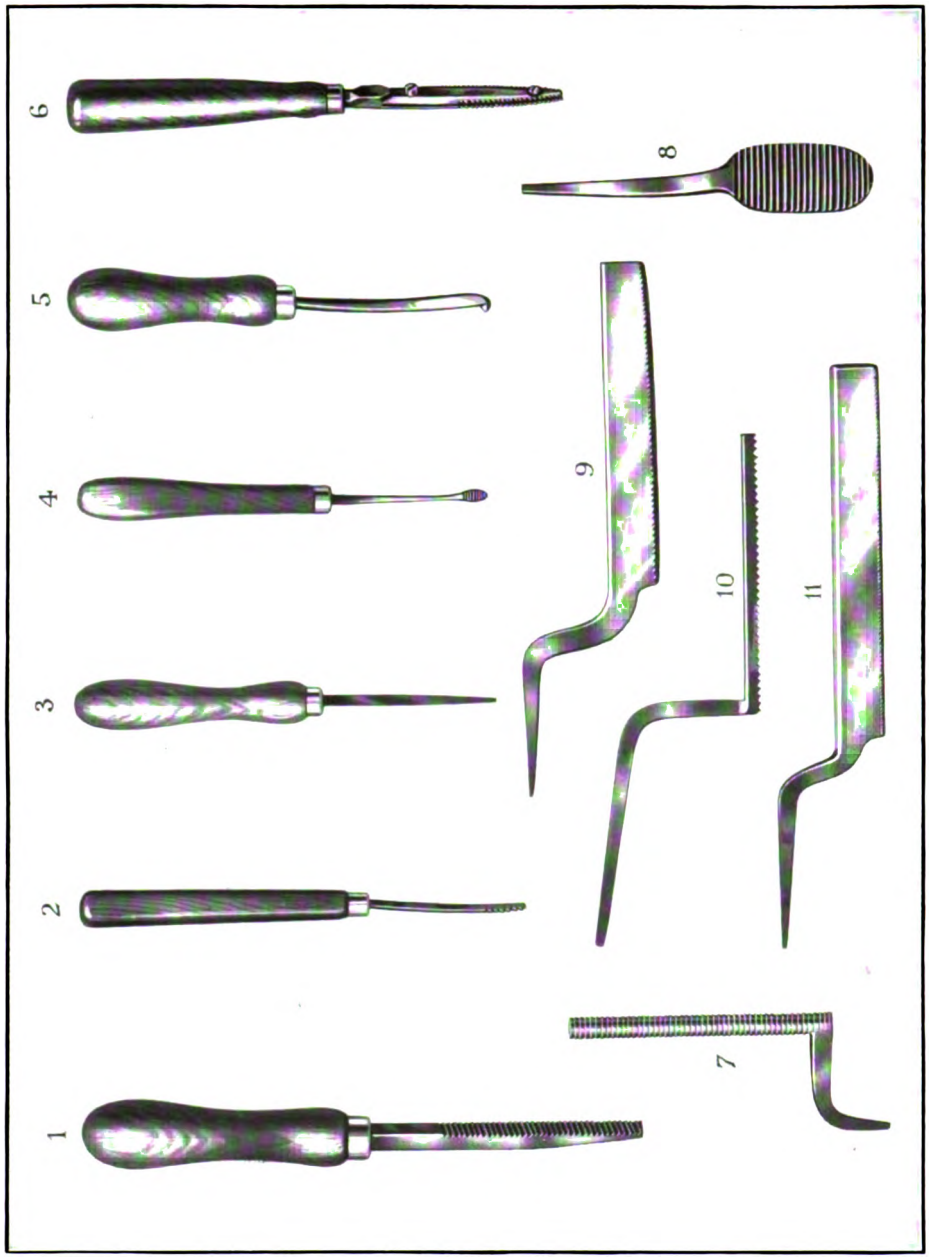

GUN FINISHERS' AND BARREL FILERS' TOOLS.

1 to 6. Gun Finishers' Tools (3 is a smooth file that has been in daily use for 53 years). 7, 8. Special Floats.

9 to 11. Typical Barrel Filers' Strikers.

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1 2 3

EARLY RIFLES.

1. ELIZABETHAN PETRONEL, *c.* 1500. 2. GERMAN WHEEL-LOCK, 1652.
3. AMERICAN FLINT-LOCK, 1804.

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PLATE XVII.

GLASS FOUND IN EGYPT, PERIOD BEFORE 1200 B.C.

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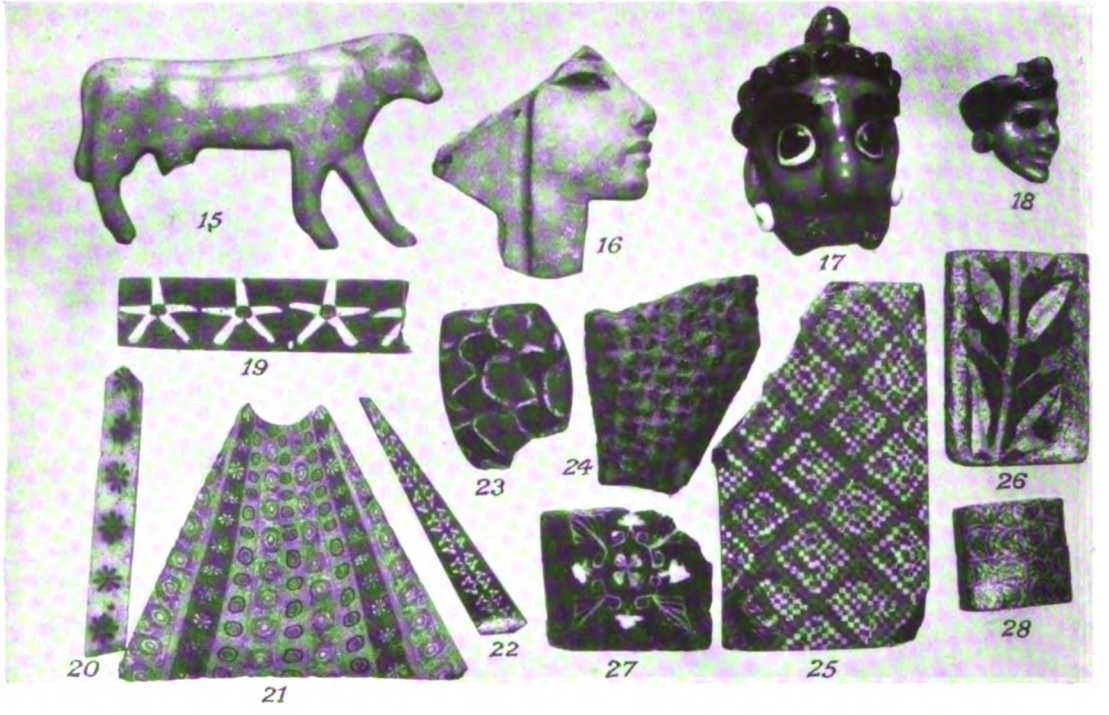

GLASS FOUND IN EGYPT, PERIOD 1200 TO 300 B.C.

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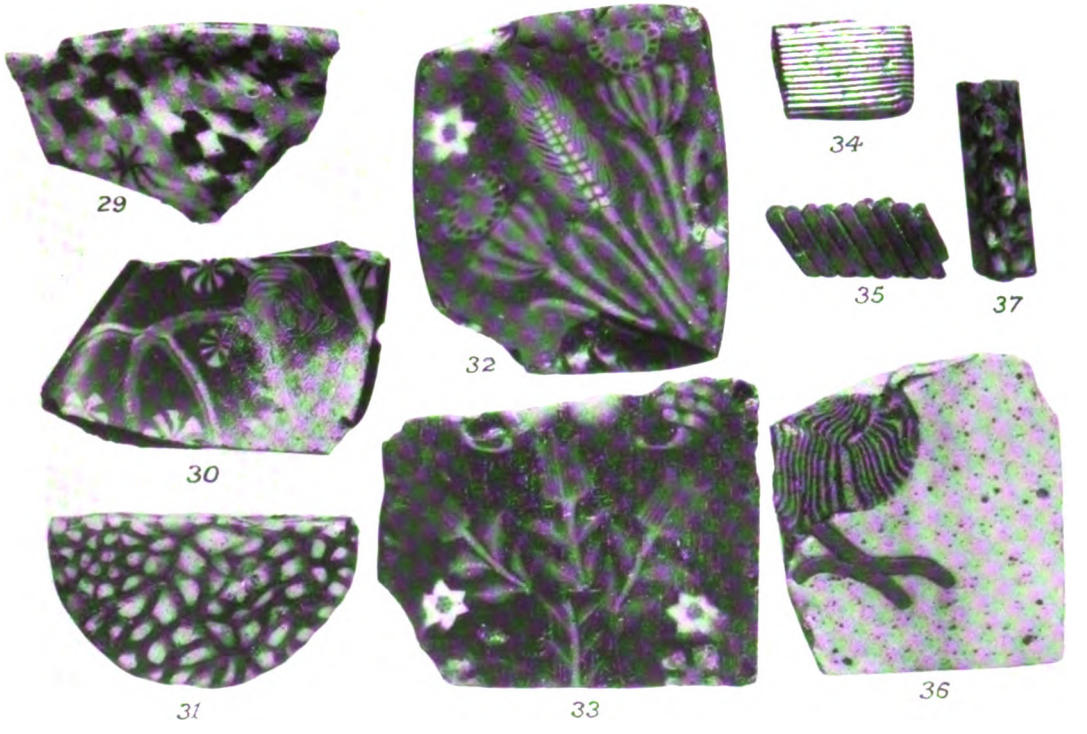
PLATE XIX.



GLASS FOUND IN EGYPT, PERIOD 300 B.C. TO 300 A.D.

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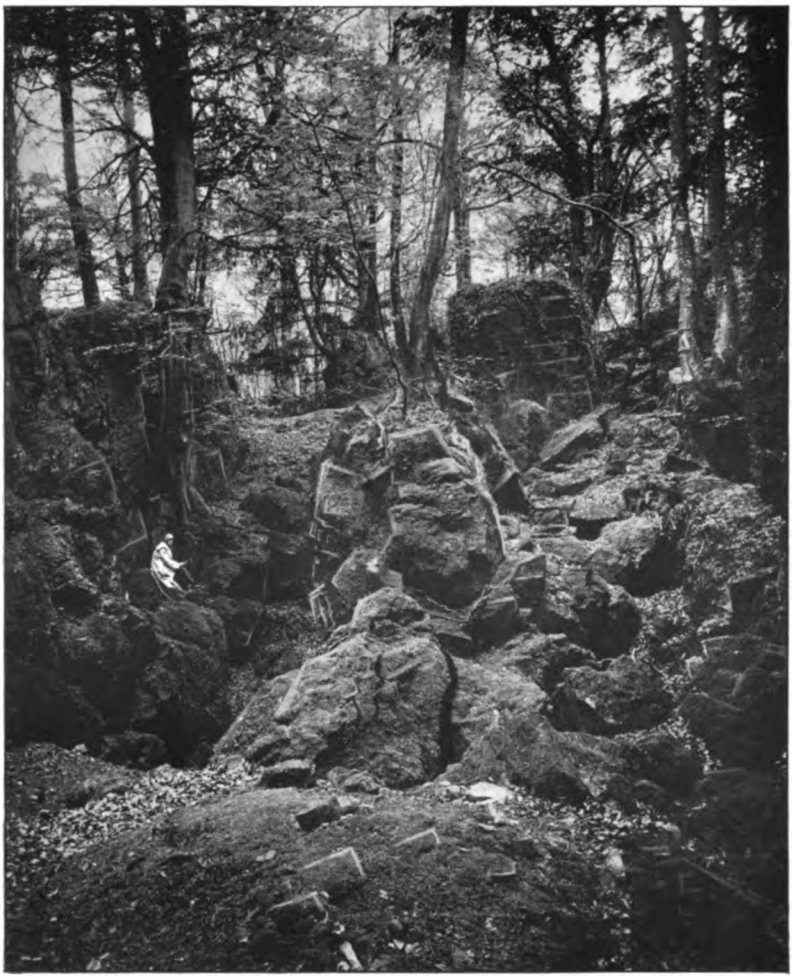

THE SCOWLES.—OLD IRON ORE WORKINGS NEAR BREAM, FOREST OF DEAN.

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REMAINS OF BLAST FURNACE, 1683, AT GUNN'S MILLS, FOREST OF DEAN.
INSET SHOWS DATE CAST ON LINTEL.

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o renew the charge, book must be brought to it.

TWO WEEK BOOK

DO NOT RETURN BOOKS ON SUNDAY

DATE DUE

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